Evaluating
Courses of Actions at the
Strategic Planning Level

THESIS

Ahmet Ozdemir, Major, TURAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF

TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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EVALUATING COURSES OF ACTIONS AT THE STRATEGIC PLANNING LEVEL

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Ahmet Ozdemir, B.S.I.E.

Major, TURAF

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Ahmet Ozdemir, B.S.I.E.
Major, TURAF

Approved:

_____	2013
Dr. Jeffery D. Weir (Advisor)	date
_____	2013
Dr. Jeffery K. Cochran (Reader)	date

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Abstract

Like almost all real life problems, Strategic planning is a good example of a problem with more than one objective. One of the most important steps of strategic planning is to generate and evaluate the courses of actions (COA) which can fulfill the mission and vision of the organization. This is a critical process since it is impractical to start the executed COA over.

In this research, value-focused thinking (VFT) is used as a decision analysis tool to assess COAs. A general model is created to select the best COA for strategic planning such as air force operation planning. To validate the model, notional courses of actions are developed, ranked, and evaluated to include using sensitivity analysis.

To my wife and family

Acknowledgments

First, I would like to express my gratitude to my country and the Turkish Air Force for this overseas education opportunity. I would, also, like to express my sincere appreciation to my faculty advisor, Dr. Jeffery D. Weir. His assistance and suggestions as well as his guidance for this research were unprecedented. I would like to thank to Dr. Jeffery K. Cochran, my reader, his precious input. I would like to acknowledge and thank the SME group, whose insightful comments made this work a valuable product. Finally, I would like to thank my wife, family and friends for their continuing support, encouragement, and patience.

Ahmet Ozdemir

Table of Contents

List of Figures

Page

List of Tables

Page

List of Terms

AD	Area defense
AFDD	Air Force Doctrine Document
AR	Air Refueling
AT	Acceptable Threshold
AWACS	Airborne Warning and Control System
AWX	All Weather Fighter
CAOC	Combined Air Operations Centre
CAP	Crisis Action Plan
CAVOK	Ceiling and Visibility are OK
CCDR	Combatant Commander
CCIR	Commander's Critical Information Requirement
CDR	Commander
COA	courses of action
CT	Critical Threshold
DA	Decision Analysis
DCA	defensive counter-air
DM	Decision Maker
ESC	Escort
HVAA	High Value Airborne Asset
JFSC	Joint Forces Staff College
JOPP	Joint Operation Planning Process
JP	Joint Publication
JSTARS	Joint Surveillance and Target Attack Radar System
MOE	Measure of Effectiveness
MOP	Measure of Performance
NDU	National Defense University
OCA	Offensive Counter-Air

OPLAN	Operation Plan
OPORD	Operations Order
P&G	Procter & Gamble
PD	Point Defense
ROE	Rules of Engagements
SA	Surface Attack
SDVF	Single Dimension Value Function
SEAD	Suppression of Enemy Air Defenses
SME	Subject Matter of Experts
SR	sun rise
SS	Sun Set
SW	Sweep
TPFDD	Time-Phased Force and Deployment Data
TURAF	Turkish Air Force
VBA	Visual Basic for Applications
VFT	Value-Focused Thinking

EVALUATING COURSES OF ACTIONS AT THE STRATEGIC PLANNING LEVEL

I. Introduction

"If you are planning for one year, grow rice. If you are planning for 20 years, grow trees. If you are planning for centuries, grow men". (Chinese Proverb)

1.1 Background

The word `strategy' originated within a military context (Albrechts 2004). The term strategy derives from the Greek word `strategia', meaning "generalship", itself formed from 'stratus', meaning "army", and '–ad', "to lead" (Evered 1983). Sun Tsu's classic 'The Art of War', written about 500 BC, is regarded as the first treatise on strategy (Tzu and trans. R. 1988).

Webster's dictionary (Merriam-Webster 2012) defines strategy as `strategia', `` the science and art of employing the political, economic, psychological, and military forces of a nation or group of nations to afford the maximum support to adopted policies in peace or war".

Today, many of the principles of the military approach on strategy are used in business sectors. Although there are some differences between military and business approaches, the common sense of 'Strategy' is about winning. However, there is little agreement on the definition of strategy because some of the elements of strategy have universal meanings that can be applied to any organization. Some other definitions of strategy are as follows:

- A plan of action designed to achieve a long-term or overall aim; the art of planning and directing overall military operations and movements in a war or battle (Oxford-Dictionary 2012).
- Strategy is the direction and scope of an organization over the long-term: which achieves advantage for the organization through its configuration of resources within a challenging environment, to meet the needs of markets and to fulfill stakeholder expectations (Johnson and Scholes 1999).
- Strategy is the art of creating value. It provides the intellectual frameworks, conceptual models, and governing ideas that allow a company's managers to identify opportunities for bringing value to customers and for delivering that value at a profit. In this respect, strategy is the way a company defines its business and links together the only two resources that really matter in today's economy: knowledge and relationships or an organization's competencies and customers (Normann and Ramirez 1993).
- American business historian, Alfred D. Chandler in 1962, defines strategy as "the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out those goals" (Chandler 1962).

The planning makes us prepare a better future. It helps to formulate methods or means to achieve a desired objective or goal in advance of execution. The term strategic planning, likewise strategy, has lots of definition regardless of organization. The definition which we will use in this thesis was derived from Joint Publication (JP) 5.0.

The strategic planning helps planning group to provide guidance and instructions on policy, strategy, plans, forces, and resource requirements and allocations essential to successful execution of the objectives and the directives. It also consists to assess existing capabilities, to evaluate the risk, and to regard the changes for consideration by subject matter of experts to clarify decision making and identify new contingencies that may guarantee deliberate planning and the commitment of resources.

1.2 Problem Statement

Decisions in organizations can range on a spectrum from operational and tactical through to strategic (G.Dyson 1990). There should be widespread incorporation between the levels of the organization during the planning phase. A key piece of the strategic planning process is to develop and evaluate the strategic options. In other words, it is critical to determine a definite course of action (COA). After executing a selected COA, it will be hard to go back and be difficult to undo the actions. The planning process must be concerned with evaluating options before action is taken and be concerned with the future impact of the proposed decisions (G.Dyson 1990).

1.3 Scope of the Research

In this research, value-focused thinking (VFT), as a decision analysis tool, is used to evaluate COAs for strategic planning. A model with notional data is set up to obtain scores. As a case study, the model that is generated to select the best COA for strategic planning is implemented for air force operation planning.

This research will lead the planners to utilize a methodology which guides them to develop and asses COAs. This research will also force commanders and decision makers to realize the importance of their intent because the model will rank the alternatives with their weights.

1.4 Research Questions

The main research question is:

"Which course of action (COA) is the best for the given scenario for strategic planning in order to achieve the objectives?"

There are also three other sub level questions to be answered.

First:

"What kind of values and measurements will be used in the model?"

Second;

"How can these measurements be quantified?

Finally,

"What are the weights of the values and the measurements in the model to evaluate the COAs?"

1.5 Assumptions

As it is anticipated, strategic planning is a very difficult concern. There are some assumptions made to outline the problem in this study.

1. At least two course of actions have to be developed in strategic planning,

2. The defensive side of counter-air has two parts; active and passive air defense operations. Active air defense operations are assumed sufficient to measure defensive facet of any COA.
3. The legitimacy of the operational plan is assumed to be assessed as acceptable.
4. There exist active air defense, air superiority, and target and task priority analysis.

1.6 Organization

This thesis has five chapters. The literature review, chapter 2, covers strategic planning, operation planning, decision analysis, and value-focused thinking. As a case study, air force operation planning courses of actions selection is detailed under chapter 3 utilizing a VFT approach. Chapter 4 discusses the generated alternatives and their ranks as well as evaluates and analyzes the COAs. Finally, chapter 5 consists of the outcomes of the analysis, the contributions and restrictions of the study, and potential areas of prospective work.

II. Literature Review

"If you don't know where you're going, any road will take you there."
(Lewis Carroll - Author of Alice in Wonderland)

In this chapter, Strategic planning is first explained by its most common process with a business sector example. Then, decision analysis, value-focus thinking and operation planning are elucidated respectively. Finally, Section 2.4 explains the contribution of this research.

2.1 Strategic Planning

Planning is a very important task in managing modern organizations. In the earliest treatises it has been defined as "assessing the future and making provision for it" (Fayol 1949). Planning is simply deciding where you want to go and how you want to get there (Anthony 1985).

The foremost mission of planning is to find the best appropriate and effective courses of actions. Afterwards designing the execution, how to implement the course of action, should be detailed in the planning before taking action. Indeed, there are two basic elements to any plan; deciding on a goal or objective and deciding on the best way to reach there (Anthony 1985).

Traditional approaches to planning used by organizations can be summarized in terms of a number of steps as the followings (Radford 1988):

1. Information gathering.
2. Review of organizational missions and objectives.
3. Choice between alternative courses of actions.

4. Development of detailed plans and allocation of resources to activities.
5. Implementing of the detailed plans.
6. Evaluation of the results of the activities as a preliminary to a new planning cycle.

Today, there are some other important considerations which have effects on planning:

1. The widespread scope of the activities of the modern organizations.
2. Other than profit or efficiency, organizations should think about some side effects. For example, reducing the hazardous emission or waste products, occupational health, customer satisfaction, collateral damage…etc.
3. The growth of the communication devices like media, internet have resulted in many parts of society becoming involved in issues of the day and being much better informed with regard to them.
4. Today organizations should operate in a more dynamic situation rather than static and the dynamism getting velocity every day.

These kinds of development make the planners think strategic. As it is mentioned in the introduction, Chapter 1, strategy and strategic planning are widely used terms, however, difficult to define. In fact, there are plenty of definitions but there is no real consensus concerning which is best (Schwenk 1988). The most general description of the strategic planning can be defined as it is a reiterative process to envision the objective of the organization and develop the necessary actions and procedures to reach that goal before taking action.

For the business sector, strategic planning is a way of gaining more profit. It provides a path to make a major investment decision such as new product, new plant, budget allocation…etc. On the other hand, for the military organizations, the principle of strategic planning is to allocate the resources efficiently and reach the highest effectiveness. The military approach to strategic planning is a little profound. Efficiency, the transforming of inputs to outputs, is the focus of the operating environment, whereas effectiveness, the degree to which future goals are achieved, is focal point of the strategic planning function (King and Cleland 1978).

Strategic planning is required to make strategic decisions over the major plans for the organization. The main purpose of the strategic planning is to select future areas of activity and future courses of action for the organization (Radford 1988).

There is an agreement over most of the key effects of strategic planning (Schwenk 1988) (Anthony 1985) (Goodstein, Nolan and Pfeifer 1993) (King and Cleland 1978). The followings are the summary of the key effects of strategic planning:

1. It forces you to analyze and detect the changes in the external and internal environment.
2. It is performed at the top of the organization by a planning committee with the vision of the politics and assessment of the organization's strengths and limitations.
3. It allocates the large amount of the resources of the organization. That involves large resource commitments and the possibility of large gains and losses.
4. It directs the organization.

5. It provides the possible outcomes of decision based on organization's objectives.
6. It allows considering wide range of alternatives or courses of actions.
7. It is a best way to have and consider the lesson learned information due to the successes, failures and mistakes of the past experiences.
8. A practical strategic plan represents slicing up the organization's objectives and goals and determining which obtain priority.

Strategic planning processes are built up to get the effects listed above. There have been lots of process examples today (Barksdale and Lund 2006), (Bryson 1995), (NAMAC 2009), (McKay 2001), (FGDC 2009). For instance, National Child Welfare Resource Center utilizes the framework, shown in Figure 1, consisted of four basic stages for their strategic planning.

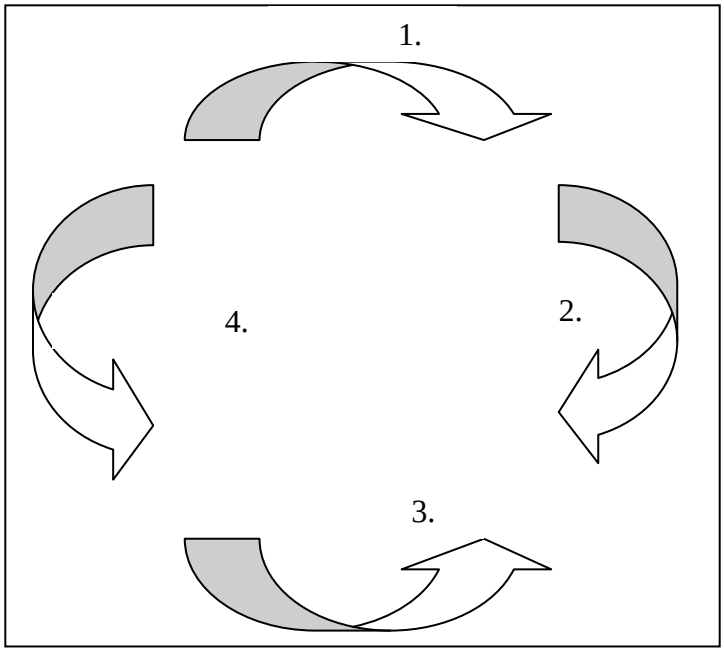

Figure 1 Four Stages of Strategic Planning

Besides this basic process, there are lots of step by step guidance for strategic planning in the literature. For example FORBES defines their process in five steps at their web site. The five steps to a strategic plan of FORBES are the followings (FORBES 2011):

1. Determine where you are.
2. Identify what's important.
3. Define what you must achieve.
4. Determine who is accountable.
5. Review. Review. Review.

Furthermore, Dr. LM Foong lined up the process into seven steps in his total quality management article (Foong 2007):

- Step 1 - Review or Develop Vision & Mission
- Step 2 - Business and Operation Analysis
- Step 3 - Develop and Select Strategic Options
- Step 4 - Establish Strategic Objectives
- Step 5 - Strategy Execution Plan
- Step 6 - Establish Resource Allocation
- Step 7 - Execution Review

In the details of the seven steps strategic planning process above, Dr. Foong mentioned, the possible strategic options should be developed based on the inputs from stakeholders (step 1) and/or Business and Operation analysis (step 2).

Figure 2 Where to use VFT

In this thesis, as shown in Figure 2, step 3 is studied to generate a proper tool to prioritize, evaluate and help planners in developing courses of actions based on the possible strategies.

2.1.1 An Example from Business Sector

There exist lots of strategic planning studies in the business sector. In fact strategic analysis is needed to make a plan as mentioned in the following section. For example;

Procter & Gamble (P&G) is America's biggest manufacturer company of consumer goods including 50 Leadership Brands in two key areas: Beauty and Grooming, Household Care (Gamble 2012).

In the essay (UKessays 2008), a strategic analysis of P&G has been done using the data between 2005 and 2007. It consists of external and internal analysis of P&G, assessment of performance in terms of efficiency, effectiveness, and return on investors, a review of options available and recommendations for structures, systems, and policies.

Quality enhancement, technology enhancement, cost reduction, advance localization, focusing on growing market, and some others are recommended as strategic

options to develop P&G. Which is/are the best choice/s for P&G regarding the goal of the company? There should be an evaluation tool to get the best option/s.

2.2 Decision Analysis

Making a decision is one of the crucial things in life for everybody. What is a decision? The most widespread definition for decision is “An irrevocable allocation of resources” (Hazelrigg 1996). A decision is an action that leads to an allocation of resources or an outcome that is irrevocable or nearly so because it would be very costly to restore the allocation that existed prior to the action (Howard, Decision analysis: Applied decision theory 1966).

The phrase decision analysis is first used by Howard in "Decision Analysis: Applied Decision Theory" to explain a practical process for the balancing of the factors that influence a decision when the outcomes are uncertain (Howard, Decision analysis: Applied decision theory 1966). This process is the product of a study about how individuals make decisions when faced with an option that has an uncertain outcome which merge systems engineering methods and statistical decision theory (Schultz, Borrowman and Small 2011).

Nowadays, it is hard to make a decision by ourselves. Modern organizations follow some process to make a decision in all levels of the organizations. Kirkwood explains that good decision making provides a structured method for including the information, opinions, and preferences of the various relevant people into the decision making process (Kirkwood 1997).

There are two different classifications for decision analysis regarding the purpose of it. Skinner divides the term decision analysis into two district disciplines of normative and descriptive theory (Skinner 2001) whereas Keller adds prescriptive decision analysis (Keller 1989) and makes it three. Normative approach describes how people should make a decision, while descriptive approach tries to explain how people actually make decisions (Skinner 2001). In addition to these, prescriptive decision analysis bridges the gap between descriptive observations of the way people do make choices and the normative guidelines for how they ought to make choices (Keller 1989). In other words it prescribes the techniques for aiding decision making.

However, we make our decisions in two ways. They are how we should and how we do make decisions. In the normative perspective people use universally accepted principles or experiences as a logical guidance to make a decision. On the other hand, the descriptive perspective is studying behaviors to predict the people's actual choices for decision.

This thesis focuses on normative decision making. Normative Perspective concentrates on the development and application of decision making models built on a coherent set of axioms that people consider as providing logical guidance for their decisions (Robbins 2011).

Decision analysis is an iterative process of gaining insight and creating original alternatives to help decision makers (Howard, Decision Analysis: Practice and Promise 1988). This iterative process needs to follow a cycle, an example is shown in Figure 3, to make better decisions.

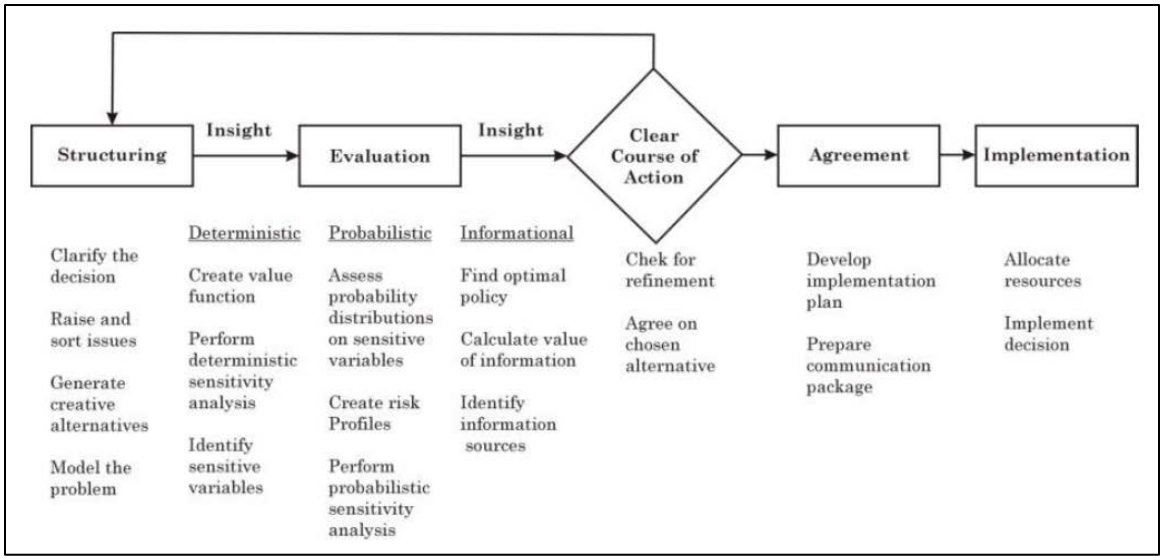

Figure 3 Decision Analysis Cycle (Skinner 2001)

In order to make an evaluation in decision making cycle, two main concepts, values and objectives, should be used to guide the decision analysis as a basis. Values "are what we care about" and objectives "[are statements] of something that one desires to achieve" (Keeney, Value-Focused Thinking 1992).

There are different kinds of methodologies to solve the decision problems. One and the more advantageous (Jeoun 2005) of these approaches is value-focused thinking:

2.2.1 Value-Focus Thinking

The theory behind value-focused thinking is uncomplicated. Instead of beginning from identifying alternatives, it will be more helpful to start examining what is important to decision maker/s (Boushell 1998). As shown in Figure 4, there are lots of benefits to use VFT for evaluating alternatives.

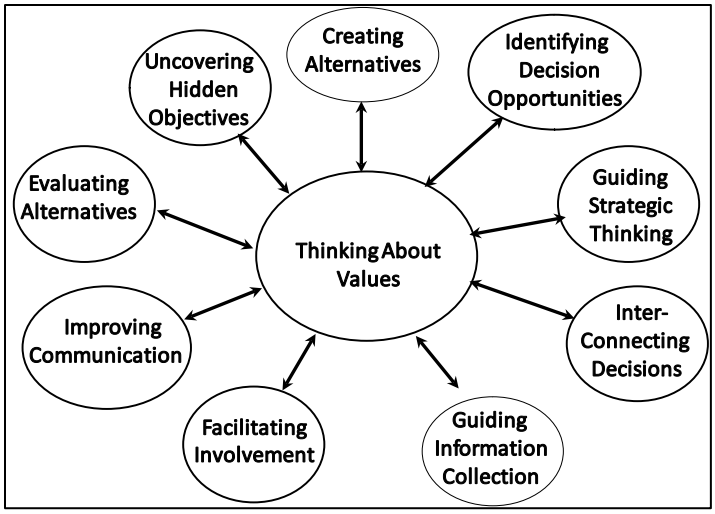

Figure 4 Benefits of VFT (Keeney, Value-Focused Thinking 1992)

The greatest benefits of value-focused thinking are being able to generate better alternatives for any decision problem and being able to identify decision situations that are more appealing than the decision problems that confront you (Keeney, Creativity in decision making with value-focused thinking 1994).

Basically, the VFT process starts with an initial value hierarchy structure based on weights from decision maker and/or subject matter expert opinion. This is followed by ranking the alternatives, doing the sensitivity analysis, and then presenting the results (Marks 2008). The ten steps (Shoviak 2001) for the VFT process are shown in Figure 5.

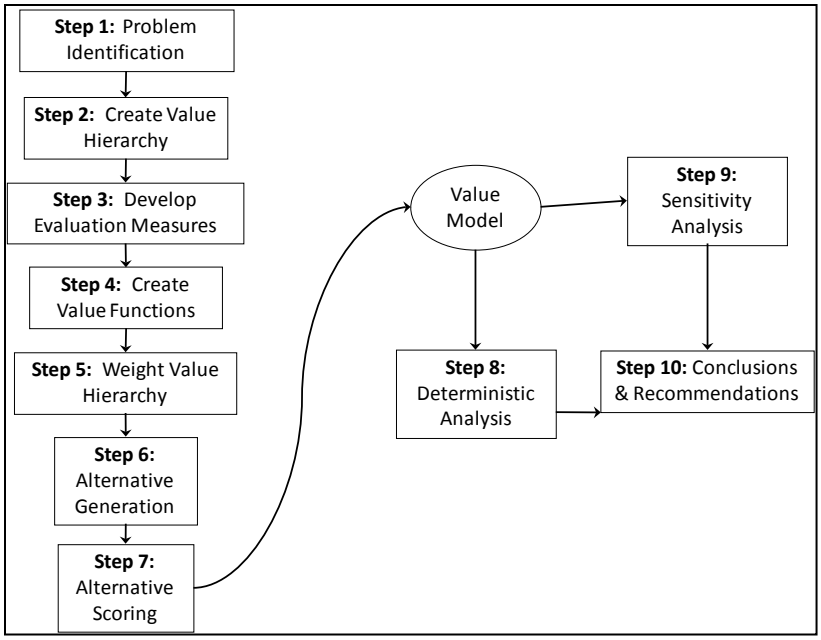

Figure 5 Value-Focused Thinking 10-Step Process (Shoviak 2001)

The details of the steps for the process of VFT approach are explained in the following chapters. Step 1 through step 5 is detailed in Chapter 3, Step 6 through step 9 in Chapter 4, and finally step 10 in Chapter 5.

2.3 Operation Planning

An operation plan is defined as any plan for the conduct of military operations prepared in response to actual and potential contingencies (JP-1-02 2010). It should contain a full description of the concept of operations, all annexes applicable to the plan, and a time-phased force and deployment data. It is also called an OPLAN.

Military organizations use a path to get their OPLAN. It is a kind of function that leads the planners. For example, United States of America Joint Force operation planning

consists of numbers of elements, including three broad operational activities, planning functions, and a number of related products (see Figure 6). (JP-5-0 11 August 2011)

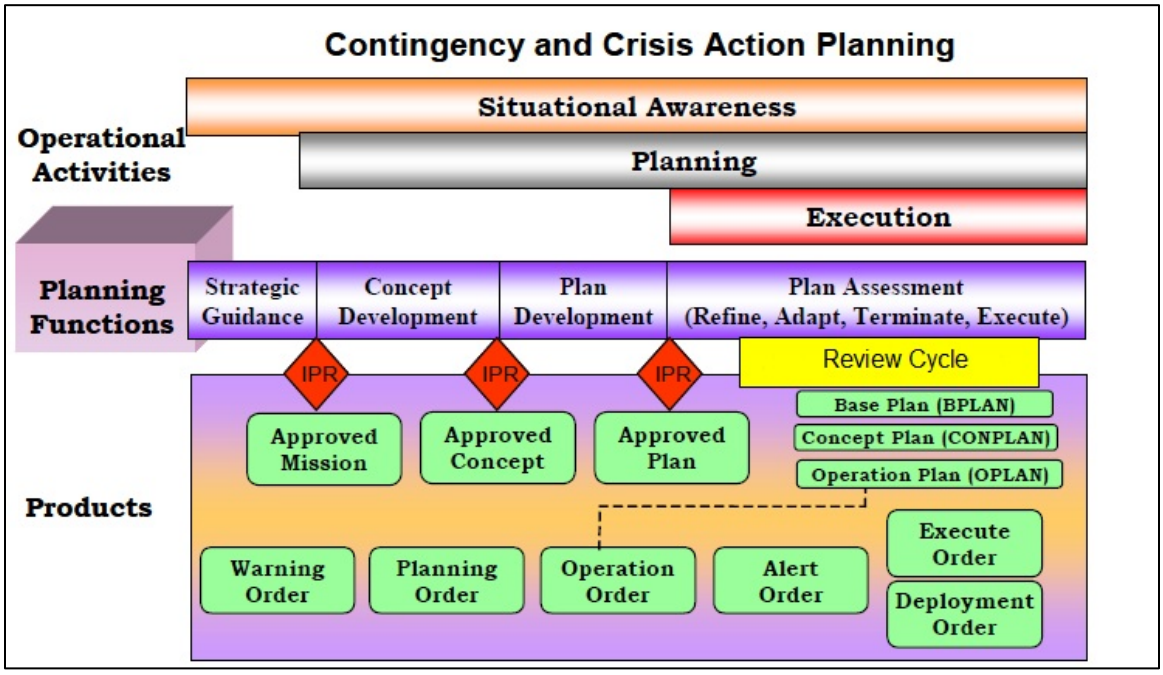

Figure 6 Planning Functions (JFSC-NDU 2010)

Operational activities are situational awareness, planning and execution. The planning functions have four subordinate functions: Strategic Guidance, Concept Development, Plan Development, and Plan Assessment. Each of these four functions is further broken down into steps (see Figure 7) (JFSC-NDU 2010).

2.3.1 Planning Phases

In a nutshell, an OPLAN starts with assessing the military situation and then needs to develop several possible options or COAs that will resolve the military problem. Overall, Joint Operation Planning Process (JOPP) is a four-function, seven-step process

that culminates with a published Operations Order (OPORD) in crisis action plan (CAP) and results in an OPLAN (JFSC-NDU 2010).

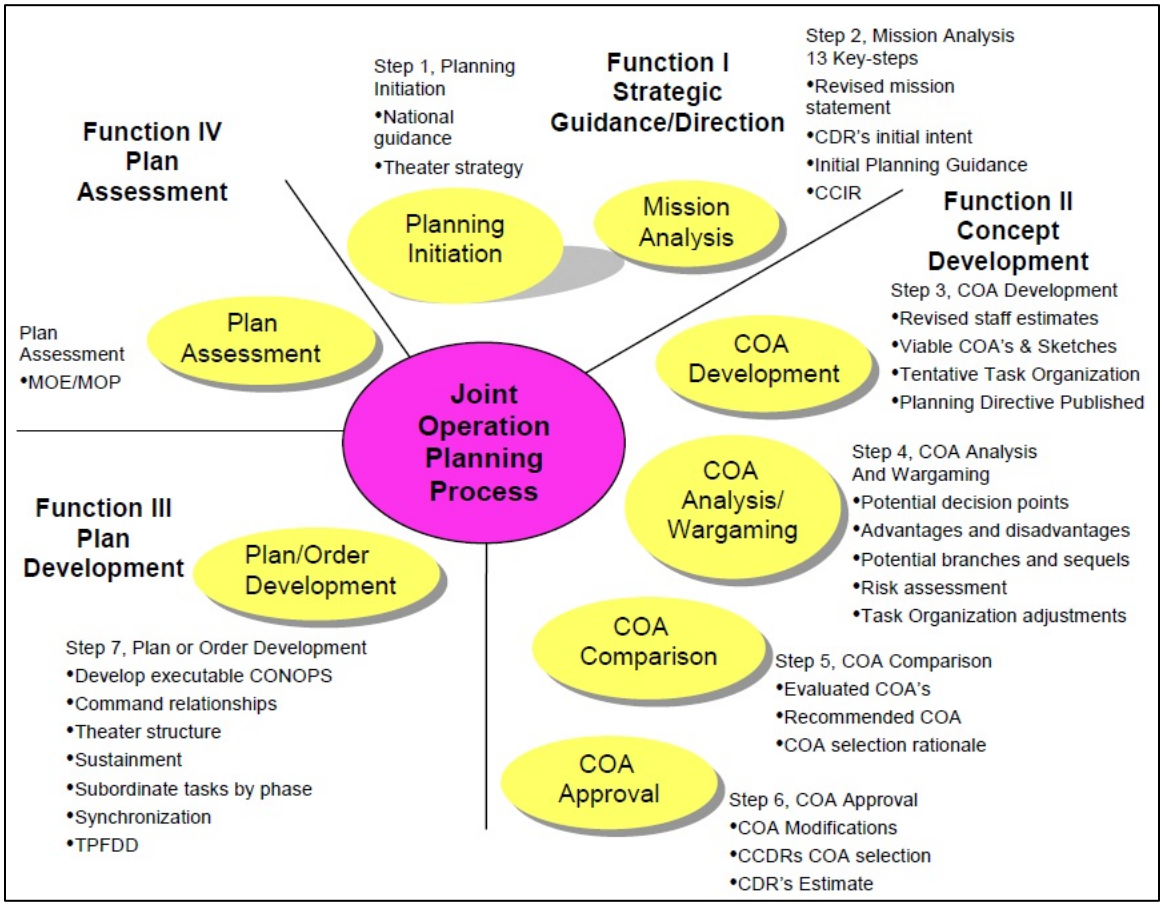

Figure 7 JOPP (JFSC-NDU 2010)

2.3.2 Courses of Action (COA)

The commander, decision-maker, is suppose to select the best or at least the optimum COA depending on goals, objectives, and the estimates. Each COA should have some information. In Operational Art and Campaigning Primer of Joint Forces Staff College (JFSC), these information are defined as the following (JFSC-NDU 2010):

- Type of forces will execute the tasks.

- Type of action or tasks are contemplates.
- The time of the tasks will begin.
- The location of the tasks will occur.
- For what purpose the action is required.
- The way of the available forces will be employed.

In general, a course of action is any option available to the operational commander that, if adopted, would potentially lead to the accomplishment of the mission (Vego 2007). While developing each COA, Commanders and planners should see the resources, planning assumptions declared by the higher publication or initial order for planning, limitations, the current situation of friendly forces, and the consequences of Rules of Engagements (ROE), as a whole. Briefly, the emphasis should be on the entire mission (Nicholas 1959).

Indeed, each course of action should be fundamentally different from all others (Vego 2007). It will be a waste of time if the operational commander and staff develop similar COAs.

The staff focuses their efforts and concentrates valuable resources on the most likely scenarios (JFSC-NDU 2010). All COAs selected for analysis must be valid. A valid COA is one that is adequate, feasible, acceptable, distinguishable, and complete (JFSC-NDU 2010):

- Adequate - Can accomplish the mission within the Commander's guidance.
- Feasible - Can accomplish the mission within the established time, space, and resource limitations.

- Acceptable - Must balance cost and risk with the advantage gained.
- Distinguishable - Must be sufficiently different from the other courses of action.
- Complete - Must incorporate: Objectives, major forces required concepts for deployment/employment/sustainment, time estimates, and military end state and mission success criteria.

The assessing of COAs is the most important part of the concept development function of the planning process. Assessing should at least include considerations of the weather, terrain, and friendly and enemy forces; relative strength; composition and dispositions; logistic support; and requirements for future operations (Vego 2007). At the operational and strategic levels, political and other nonmilitary aspects of the situation should also be considered (Nicholas 1959).

The purpose of comparing COAs is to spot and recommend the best COA that will provide the highest probability of success. In addition, comparing COAs helps Commanders and planners recognize the differences between each COA, the advantages/disadvantages, and the risks. So, how can we compare COAs in a most accurately and efficiently?

2.4 Research Contribution

As mentioned above, for all kind of strategic planning process there exists a necessity for evaluating the courses of actions. Although the objective of this thesis is to generate a methodology by using VFT to compare the COAs, operation planning in military is used as an example.

The VFT approach can be easily utilized as a COA comparison tool for all kind of complex military operations. It provides sensitivity analysis to decision makers and the planners as well as the other benefits shown in Figure 4. Sensitivity analysis can help you check the strength of your weights for your measurements. In brief, you can create more realistic models and significantly increase the accuracy of alternative rankings since you will know how all of your weights affect your model. All data and the examples that are used in this thesis are notional because of a potential classification issues.

III. Methodology

"If we knew what it was we were doing, it would not be called research, would it?"
(Albert Einstein)

A systematic usage of VFT is implemented for selecting a best COA. This methodology can be easily used for any kind of strategic planning. In this thesis, this methodology is explained over air force operation planning. As for the other kinds of planning; the objectives, the purposes and the goals of it have to be understood by the COA developers.

3.1 Model Formulation

As mentioned in chapter 2, we need to use a method to evaluate the COAs. Hence, VFT is a good fit for these kinds of problems. While moving forward on the steps shown in Figure 5, an excel-VBA based tool called Hierarchy Builder Version 2.0 (Weir 2012) was applied in this research. It has been used before and validated by the other researches (Malyemez 2011) (Kim 2012) (Riaz 2012).

The purpose of building a VFT model is similar to any kind of model. Even though it has lots of motivation; in general, a model is built to get understanding of a complex problem for making a decision. Almost all real life problems have more than one objective. To conduct a multi-objective value analysis, it is necessary to determine a value function, which combines the multiple evaluation measures into a single measure of the overall value of each evaluation alternatives (Kirkwood 1997). Kirkwood defines required functions to determine an overall value function with the followings:

- Single dimensional value functions are specified for each evaluation measure.
- Weights are specified for each single dimensional value function.

The key issue in these functions is who will set the values and associated weights to the model or the problem. Keeney has a simple explanation for this, “value models of any stakeholder interested in a particular decision context are appropriate (Keeney, Value-Focused Thinking 1992)”. On the other hand, when it is clear who is the decision maker in a given decision situation, it is desirable to quantify that decision maker’s values (Keeney, Value-Focused Thinking 1992).

In any kind of strategic planning if we are able to get the decision maker’s values and weights, it will make it easy to reach the ideal model since the decision maker will have the last word. For operation planning, the decision maker is the Commander who is also the busiest person in that time. In fact, most of the operation plans like contingency plans are made in peacetime which means that it is not guaranteed the Commander will be the same person in the crisis situation. Therefore, a group of experts’ values may be better than an individual values. Values that are constructed from the combined opinion of subject matter of experts (SME) will give more productive results. For all the reasons above, SME values and weights are used in this thesis. There are two members of the SME group. All the group members are interview by the author.

One is a Major in Turkish Air Force (TURAF). He has a degree of Bachelor of Science in Aeronautical Engineering and a Master’s of Science in International Relations. He has graduated from Turkish Air Force College. He has more than 800 hours in the F-

16 and over 400 hours of instruction to pilots. He is still assigned in Combined Air Operations Centre Uedem (CAOC-U) - Uedem, Germany.

The other is also a Major in TURAF. He has a Bachelor of Science degree in Aeronautical Engineering. He has graduated from Turkish Air Force College. He has more than 1000 hours in the F-16. He is still assigned in Turkish Air Force College as an instructor.

3.2 Problem Identification

The model for getting a decision should be started form the first step. It is defined by Keeney as identifying the set of objectives appropriate for the decision situation (Keeney, Value-Focused Thinking 1992). And it is for the decision-maker to correctly describe the problem that needs to be solved. Incorrectly identifying the problem will often amount to nothing more than wasted effort, time, and money (Shoviak 2001). There are many ways to identify the objectives. Keeney list them as in Table 1 (Keeney, Value-Focused Thinking 1992).

Table 1 Devices to use in identifying objectives

#	**Devices**	**Definition**
1.	A wish list	The answer of "if you had no limitations at all, what would your objectives be?"
2.	Alternatives	Articulations of the features that distinguish existing alternatives provide a basis for identifying some objectives.
3.	Problems and shortcomings	Using the reasons for concern to generate objectives.
4.	Consequences	It is quite easy to identify associated objectives if one can articulate consequences that matter.
5.	Goals, constraints, and guidelines	Goals, constraints, and guidelines can suggest objectives.
6.	Different perspective	Try to get the objectives by taking the perspectives of other stakeholders.
7.	Strategic objectives	The ultimate objectives of the decision maker.
8.	Generic objectives	Generic objectives attempt to define the concerns for all decision makers in a single decision situation.
9.	Structuring objectives	You try to define listed objectives more clearly, to relate them to one another, and to relate them to objectives not yet identified.
10.	Quantifying objectives	This process involves the identification of attributes and a construction of a value.

As mentioned before instead of decision maker, a SME group identified the problem in this thesis. As a result, the main goal is to figure out the best COA for given mission.

3.3 Creating Value Hierarchy

The foundation for any kind of decision situation is its values (Keeney, Value-Focused Thinking 1992). All the values in the model are based on the identified objectives. After identifying the objectives it is time to produce how value hierarchies can be displayed. Kirkwood suggests two ways to structure the hierarchy (Kirkwood 1997). If the alternatives are known, then a *bottom-up* or *alternatives-driven* approach may be appropriate. On the other hand, there might be some situation that the possible alternatives are unclear at the beginning of the analysis, and in fact one of the purposes of the analysis is to identify potential alternatives. *Top-down* or *objective-driv*en approach is used to start with the overall objectives and subdivided this to develop the evaluation considerations in successively greater detail. *Top-down* approach is used in this research due to unclear alternatives.

Keeney defines values as the following (Keeney, Creativity in decision making with value-focused thinking 1994);

"Values, as I use the term, are principles for evaluating the desirability of any possible alternatives or consequences. They define all that you care about in a specific decision situation. It is these values that are fundamentally important in any situation, more fundamental than alternatives, and they should be the driving force for our decision making. Alternatives are relevant only because they are a means to achieve values. Thus, although it is useful to iterate between articulating values and creating alternatives, the principle should be "values first." This manner of thinking, which I refer to as value-focused thinking, is a way to channel a critical resource-hard thinking-in order to make better decisions."

The evaluation consideration in each layer of a value hierarchy must be "collectively exhaustive and mutually exclusive" (Kirkwood 1997). In short, the evaluation consideration in each layer of the entire model must cover all evaluation

concerns needed to assess the alternatives. On the other hand, “mutually exclusive” or non-redundancy of hierarchy means that evaluation considerations should not overlap.

In the light of all the considerations mentioned above, it is better to generate values to get the best COA based on strategic and operational objectives that are given by strategic guidance. In this research, general objectives are built for assessing COAs. These objectives can be produced and used for any kind of air force planning.

The values that have been determined after a group discussion and identified to be of primary importance are shown in the top row. These four sub-objectives are maximizing Continuity of Forces, Effectiveness, Logistics and Utilizing Surprise. Primary objective and sub-objectives are showed in Figure 8.

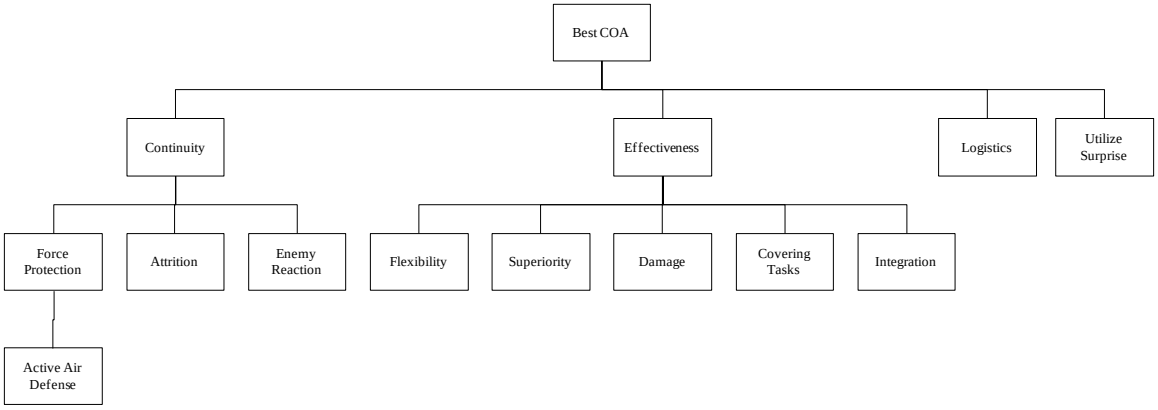

Figure 8 Values of Hierarchy

3.4 Developing the Evaluation Measures

Developing appropriate measurements to ensure the achievement of the fundamental objectives will augment the process and benefits of the model. In particular, the measurements clarify the objectives meaning, and this may lead to the creation of

desirable alternatives – perhaps even an obvious “solution” to the problem (Keeney, Value-Focused Thinking 1992).

Once we have identified the objectives, evaluation measures are created to quantify objectives. Evaluation measure scales can be developed directly or by proxy. A direct scale straightforwardly measures the degree of attainment of an objective whereas a proxy scale reflects the degree of attainment of its associated objectives (Kirkwood 1997).

The entire hierarchy with the measurements is shown in Figure 30 - Appendix *A.* VFT Hierarchy and SDVFs. The value hierarchy presents the values (in rectangles) and measures (in ovals) that will help to select the best COA.

While using *top-down* approach, these values and measures will let the user objectively rate each possible alternative based on its ability to satisfy the DM’s or SME Group’s given values.

Table 2 Measures Used to Evaluate COAs

Value (objective)	Sub-value		Defined Objectives	Measure Type	Lower Bound	Upper Bound
Continuity	Force Protection	Shield for OCA		Categorical	less than 0.5	more than 2
		Active Air Defense	Area Defense	Percentage	0	100
			Point Defense	Percentage	0	100
			HVAA Protection	Percentage	0	100
	Attrition	Friendly Loss		Percentage	100	0
	Enemy reaction	Enemy reaction to the COA		Categorical	innovative	surrender
Effectiveness	Flexibility	Closeness		Percentage	100	0
		Assumptions		Categorical	More than 3	0
		Utilize Multi Role		Percentage	0	100
	Superiority	Aerospace Superiority		Categorical	721 and more Hours	24 and less Hours
	Damage	First Priority Targets		Percentage	0	100
		Second Priority Targets		Percentage	0	100
		Third and the other Priority Targets		Percentage	0	100
	Covering Tasks	First Priority Tasks		Percentage	0	100
		Second Priority Tasks		Percentage	0	100
		Third and the other Priority Tasks		Percentage	0	100
	Integration	Additional Services		Categorical	single	all
Logistics	Speed			Categorical	More than 168 Hours	25 Hours
	Support			Percentage	0	100
	Air Mobility			Categorical	High Mobility	Low Mobility
Utilize Surprise	Weather			Categorical	CAVOK	Only Friendly Air Assets Fly
	Day/Night			Categorical	SS-1 to SS+3	SS+3 to SR-1
	Unpredictability			Categorical	Low	High

The definitions by sub-objectives of measurements shown in Table 2 are as follows:

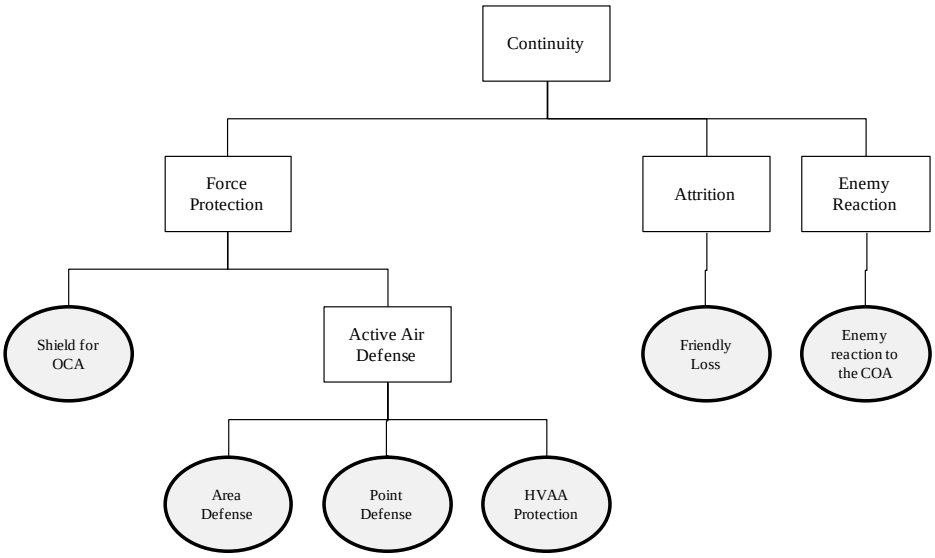

Figure 9 Continuity Hierarchy

Shield for Offensive Counter-Air (OCA): It is the ratio of the sum of Sweep (SW), Escort (ESC), and Suppression of Enemy Air Defenses (SEAD) assets over Surface Attack (SA) assets. The most valuable asset of the air force is the aircraft. The assessment of the air defense assets in an OCA package will give a proxy idea of the plan. Hence, overall OCA defense will measure the COA's defensive value. The formula to get the percentage is shown in Equation (1).

$$100 \times \frac{\sum(\mathrm{SW} + \mathrm{ESC} + \mathrm{SEAD})}{\sum \mathrm{SA}} \tag{1}$$

Furthermore, there exist two kinds of missions for aircraft during counter-air operations. One is OCA and the other is defensive counter-air (DCA). DCA consists of active and passive air defense operations including all defensive measures (AFDD-2-1.1

1998). Plans do not specify passive air operations; therefore, only active air defense is considered.

Area Defense: Area defense (AD) missions are conducted for the defense of a broad area using a combination of weapon systems. There are typical defensive counter-air weapons systems. There can be specialized applications of area defense when friendly assets to be protected are spread over a large geographical area with defined threat boundaries (AFDD-2-1.1 1998). This measurement will quantify the level of area defense of the COA. The formula to get the percentage is shown in Equation (2).

$$100 \times \frac{\sum(\text{Covered AD})}{\sum(\text{Required AD})} \tag{2}$$

Point Defense: Point Defense (PD) missions are conducted for the protection of a limited area, normally in defense of the vital elements of forces and installations (AFDD-2-1.1 1998). This measurement will quantify the level of covering Point Defense of the COA. The formula to get the percentage is shown in Equation (3).

$$100 \times \frac{\sum(\text{Covered PD})}{\sum(\text{Required PD})} \tag{3}$$

High Value Airborne Asset Protection: High Value Airborne Asset (HVAA) Protection uses fighter aircraft to protect critical airborne theater assets such as AWACS, Rivet Joint, and JSTARS (AFDD-2-1.1 1998). This measurement will quantify the level of covering Point Defense of the COA. The formula to get the percentage is shown in Equation (4).

$$100 \times \frac{\sum(\text{Covered HVAA Protection})}{\sum(\text{Required HVAA Protection})} \quad (4)$$

Friendly Loss: It is the percentage of expected Friendly Loss in the COA. There are two thresholds. These are Acceptable (AT) and Critical Thresholds (CT). AT is a reference point of acceptable percentage of friendly loss; on the other hand, CT is a value that friendly loss more than it will affect the future of the plan. 30% for AT and 50% for CT are used in this research.

Enemy reaction to the COA: An enemy may be described as rational, irrational, fanatic, rigid, flexible, independent, innovative, determined, doctrinaire, or countless other ways. Knowledge of the extent to which an enemy fits one of these categories can assist in determining the enemy's plans and how they will react to a new situation (AFDD-3-1 2000). Hence, four kinds of categorical measurements are developed; when we execute the COA, it will force the enemy to react innovative, to react irrational, to react doctrinaire or to surrender immediately.

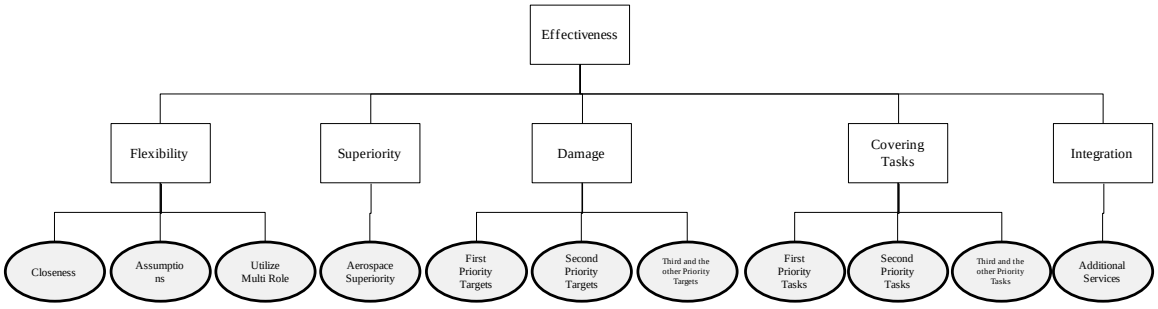

Figure 10 Effectiveness Hierarchy

Closeness: It is the distance from the battle field to the aircraft's home field. The closeness to the field will increase the options of the plan. Increased mission duration will reduce the number of targets that can be attacked in a given period (AFDD-3-1 2000). Air

Refueling (AR) is a good proxy way to measure accessibility to the aircraft's home field. The assumption for this is that AR is not desired for OCA. Therefore, in order to get the real ratio for closeness, it is better to use only OCA sorties for calculation. The formula to get the percentage is shown in Equation (5).

$$100 \times \frac{\sum(\text{OCA sories with AAR})}{\sum(\text{OCA sorties})} \tag{5}$$

Assumptions: Assumptions are used to address gaps in knowledge (JFSC-NDU 2010). If we have a crucial assumption, it will narrow our options. For this measure zero assumptions are best, one is good, two are undesirable, three and more are bad.

Utilize Multi Role: Measures the use of multi role air assets for all phases of the COA. If we use all of our multi role air assets, it will indirectly show the level of flexibility of our plan. The formula to get the percentage is shown in Equation (6).

$$100 \times \frac{\sum(\text{planned air assets in multi role})}{\sum(\text{multi role capable air assets})} \tag{6}$$

Aerospace Superiority: It is the number of hours required to achieve the desired level of aerospace superiority in the first phase of the air campaign plan of the COA. 720 and more Hours are bad; 24 and fewer Hours are good.

First Priority Targets: It is the level of estimated damage for the First Priority Targets. When the COA is executed, what percent of the planned enemy 1st priority targets are estimated to be destroyed? The formula to get the percentage is shown in Equation (7).

$$100 \times \frac{\sum(\text{Estimated Destroyed 1st priority Targets})}{\sum(\text{Planned 1st priority Targets})} \quad (7)$$

Second Priority Targets: It is the level of estimated damage for the Second Priority Targets. When the COA is executed, what percent of the planned enemy 2nd priority targets are estimated that will be destroyed? The formula to get the percentage is shown in Equation (8).

$$100 \times \frac{\sum(\text{Estimated Destroyed 2nd priority Targets})}{\sum(\text{Planned 2nd priority Targets})} \quad (8)$$

Third and the other Priority Targets: It is the level of estimated damage for the Third and the other Priority Targets. When the COA is executed, what percent of the planned enemy 3rd and the other priority targets are estimated that will be destroyed? The formula to get the percentage is shown in Equation (9).

$$100 \times \frac{\sum(\text{Estimated Destroyed 3rd and the other priority Targets})}{\sum(\text{Planned 3rd and the other priority Targets})} \quad (9)$$

First Priority Tasks: It is the level of covering the First Priority Tasks. How many of the 1st priority Tasks are covered by the COA? The formula to get the percentage is shown in Equation (10).

$$100 \times \frac{\sum(\text{Covered 1st priority tasks})}{\sum(\text{Given1st priority tasks})} \quad (10)$$

Second Priority Tasks: It is the level of covering the Second Priority Tasks. How many of the 2nd priority tasks are covered by the COA? Formula to get the percentage is shown in Equation (11).

$$100 \times \frac{\sum(\text{Covered 2nd priority tasks})}{\sum(\text{Given 2nd priority tasks})} \quad (11)$$

Third and the other Priority Tasks: It is the level of covering the Third and the other Priority Tasks. How many of the 3rd and the other priority tasks are covered by the COA? Formula to get the percentage is shown in Equation (12).

$$100 \times \frac{\sum(\text{Covered 3rd and the other priority tasks})}{\sum(\text{Given 3rd and the other priority tasks})} \quad (12)$$

Additional Services: Aerospace planners should be careful not to confine their planning to air and space assets alone, as the integration of surface maneuver units or Special Forces units in support of certain aerospace objectives can produce decisive results (AFDD-3-1 2000). Therefore, a COA planned alone is bad, with more than one is best.

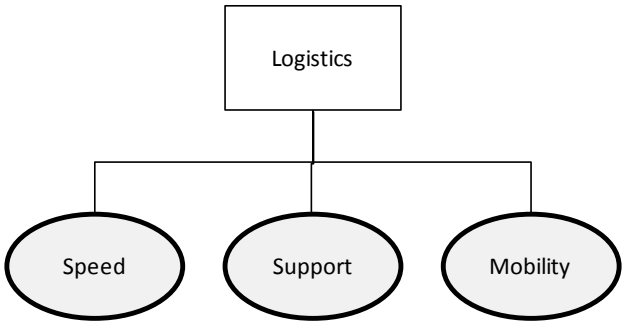

Figure 11 Logistics Hierarchy

Speed: It is the number of hours required to finish an operation and categorized as more than 168 Hours is bad whereas fewer than 24 Hours is best.

Support: Logistic support is the percentage of COA executable without foreign logistic support.

Air Mobility: It's the level of necessary air mobility for logistic requirements and categorized by three subjects. High Mobility; COA will require air mobility more than we

can support. Moderate Mobility; COA will require air mobility that we can support. Low Mobility; regular air mobility will exceed COA's requirements.

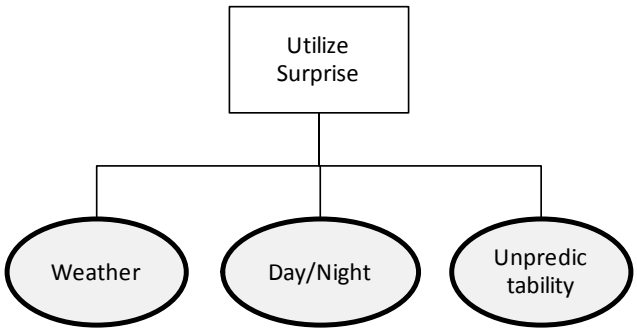

Figure 12 Utilize Surprise Hierarchy

Weather: It's the contribution to plan of the level of available weather for flying and divided into three categories by the group. COA is planned in an expected weather condition that; enemy AWX aircraft cannot fly but friendly can is best, enemy non-AWX aircraft can't fly is good and Ceiling and Visibility are OK (CAVOK) is bad.

Day/Night: This will measure the contribution to the air campaign plan of vast majority of the flights in COA's first phase. One day period divided into four categories;

SS-1 to SS+3, SS+3 to SR-1, SR-1 to SR+2, and SR+2 to SS-1. (SR: sun rise and SS: sun set)

Unpredictability: It is the unexpected direction of COA. Unexpected or surprising is a subjective approach. Therefore, it will be measured by a categorical type of measurement. High: The location or the direction of the attack can't be expected by the enemy. Medium: Level of expectation between high and low. Low: The location or the direction of the attack can easily be expected by the enemy; and that kind of plan has been historically tried before.

3.5 Creating Value Functions

Value function is a tool that helps convert multiple evaluation considerations into a single value for each alternative. The form of this function that is used in VFT is a weighted sum of functions over each individual evaluation measure (Kirkwood 1997). In order to calculate the overall value for each alternative, it is required to get every single dimension value function (SDVF) and weights for each SDVF. Section 3.6 Weighting the Hierarchy illustrates weights.

An SDVF is a function of each evaluation measure that accounts for the returns to scale before combining the evaluation measure scores; thus, it plots the measurement of the score (x-axis) versus a related value unit from zero to one (y-axis) (Kirkwood 1997). There are two basic properties of SDVF. Each of the SDVFs have been specified so that (Kirkwood 1997);

- It will be equal to zero for the least preferred level that is being considered for the corresponding evaluation measure.
- It will be equal to one for the most preferred level that is being considered for the corresponding evaluation measure.

SDVFs may vary based on the preferences of the decision maker or SME. It can be continuous or categorical; exponential or linear; monotonic or piecewise. For this thesis, each of the value functions is elicited from the group for the individual measures. These functions quantify the perceived value the group obtains from the levels of each measure. The SME group was asked for every single measurement to determine a value which gave them 80% satisfaction. In other words, the member of the group believes he

has 80% satisfaction of his value at this point for the asked measurement. The following are examples for each kind of SDVF. All other value functions are included in Appendix A. VFT Hierarchy and SDVFs; where all continuous measures are elicited using an 80% benchmark.

The SDVF of Additional Services, shown in Figure 13, is an example for categorical measurements. A COA planned alone gets zero value, planned with all services gets value of one, and planned with an additional service gets value of 0.8.

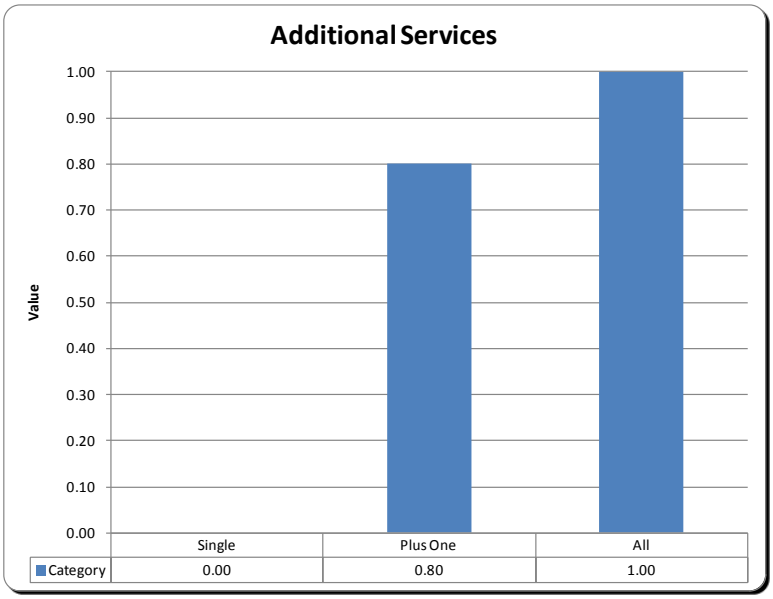

Figure 13 SDVF of Additional Services

The SDVF of Shield for OCA, shown in Figure 14, is an example of monotonically increasing continuous function. The COA with the ratio less than 0.5 gets zero value, more than 2 gets value of one, and the ratio of 1.0 gets value of 0.8. All of the values are calculated exponentially by Hierarchy Builder which uses the Equation (13). The equation for the exponential value function relies on the range of the evaluation

measure and a constant, which is donated by ρ (rho) and called the exponential constant (Kirkwood 1997). The higher value of ρ makes the function less curved whereas the smaller value makes it more curved. Since the function is increasing continuous, ρ is greater than zero. For example, the value of ρ in shield for OCA is 0.3168.

$$v_i(x_i) = \begin{cases} \dfrac{1 - e^{\left[-\frac{(x_i - x_i^L)}{\rho_i}\right]}}{1 - e^{\left[-\frac{(x_i^H - x_i^L)}{\rho_i}\right]}}, & \rho_i \neq \infty \\ \dfrac{x_i - x_i^L}{x_i^H - x_i^L}, & otherwise \end{cases} \tag{13}$$

ρ_i: the exponential constant

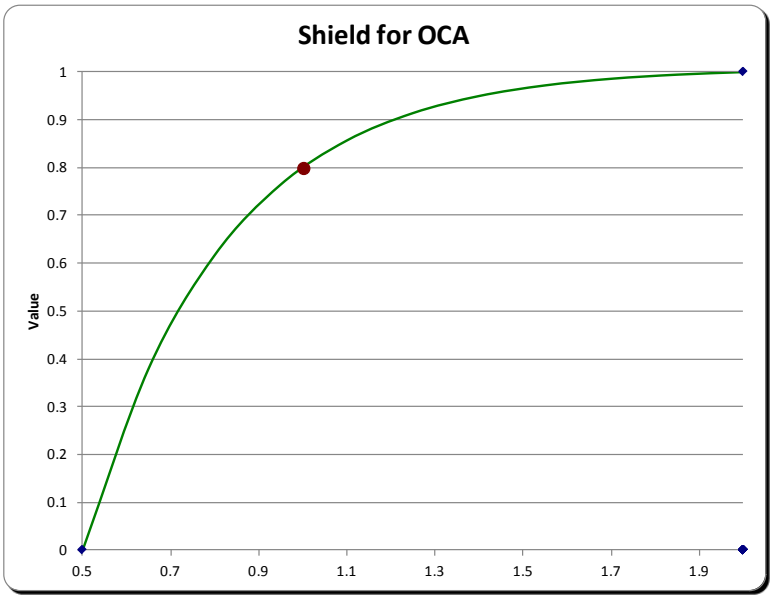

Figure 14 SDVF of Shield for OCA

The SDVF of Closeness, shown in Figure 15, is an example for monotonically decreasing continuous function. The COA with 100% gets zero value, 0% gets value of one, and 15% gets value of 0.8. All of the values are calculated exponentially by Hierarchy Builder which uses the Equation (14). Since the function is decreasing continuous, ρ is smaller than zero. For example, the value of ρ in closeness is (-136.2).

$$v_i(x_i) = \begin{cases} \dfrac{1 - e^{\left[-\frac{(x_i^H - x_i)}{\rho_i}\right]}}{1 - e^{\left[-\frac{(x_i^H - x_i^L)}{\rho_i}\right]}}, & \rho_i \neq \infty \\ \dfrac{x_i^H - x_i}{x_i^H - x_i^L}, & otherwise \end{cases} \tag{14}$$

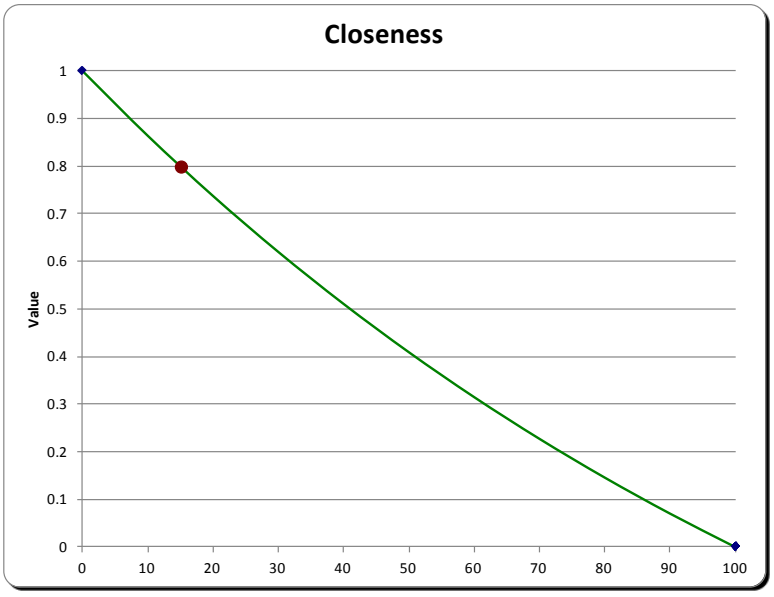

Figure 15 SDVF of Closeness

The SDVF of Friendly Loss, shown in Figure 15, is an example for piecewise linear function. The COA with 100% friendly loss gets zero value, 0% gets value of one, 30% (AT) gets value of 0.5, and 50% (CT) gets value of 0.05.

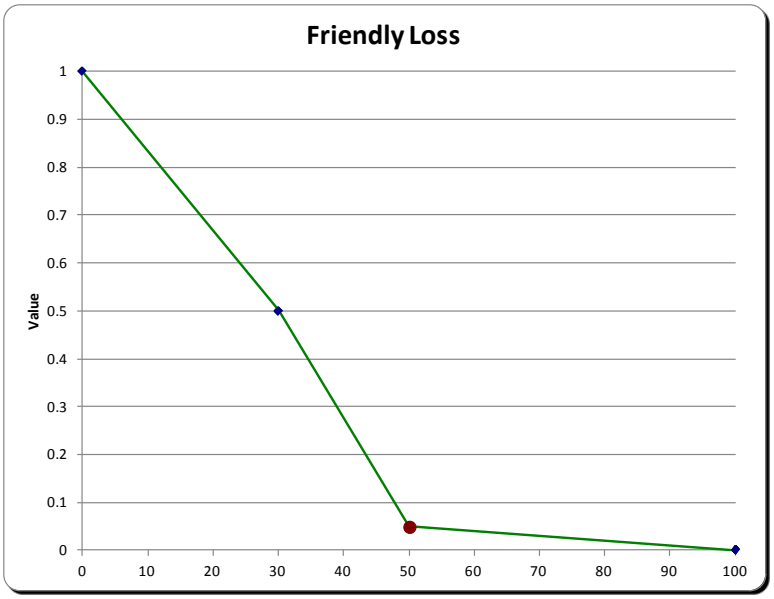

Figure 16 SDVF of Friendly Loss

3.6 Weighting the Hierarchy

Weighting a hierarchy lets the decision maker indicate how their preference for each value on the overall decision. The different values and measures were weighted to express their relative importance and comparative tradeoffs to the SME. There are different ways to get weights from a user. Hierarchy builder allows the user to get the weights in three ways; direct weighting, Swing Weights and Analytic Hierarchy Process Weighting. The main idea is to reach the overall weights of the model with the help of Equation (15).

$$v(x) = \sum_{i=1}^{n} w_i v_i(x_i) \tag{15}$$

$$\sum_{i=1}^{n} w_i = 1$$

$v(x)$: The multi-objective value function

$v_i(x_i)$: The single dimensional value function i

w_i: The weight for evaluation measure i

Direct weighting has two options which are global and local weights. Local weights measure preference of SME related to a single branch of the hierarchy. Once getting the local weights of all attributes, the global weights can easily be calculated. Shortly, global weight is the product of corresponding branch's local weights of all tiers above the attribute until reaching the top of the hierarchy. For example, Force Protection has a local weight of 0.429 and Continuity has a local weight of 0.500, so Force Protection has a global weight of 0.214.

In this thesis, the local weights were assigned using a "top-down" approach where tradeoffs were made between the measurements or values at the same tier. SMEs were first asked to find the least valuable measure or value of that tier. We set the weight of that measure to one. Then, they were asked how many times more important were the others than the least one. After all the measures or values were done in that tier, the points are normalized to sum to one. Lastly, all of the measures were weighted relative to one another within each branch.

During the interview process with the SME group we needed to ensure that each of these values was a reasonable weight for each of the measures. It is noted that to find out the best COA the most important branch is the "Continuity" branch which accounts for 50% of the decision's value. The most important single measure is Friendly Loss, accounting for about 21% of the decision's value. The least important branch is the

“Utilize Surprise” branch which accounts for about 5% of the value. The least important individual measure is “Weather” which accounts for about 0.5%. The results of the weighting process are shown in Table 3.

Table 3 Local and Global Weights of the Best COA

Objectives and Measures	Local	Global	Below	Tier	Type
Continuity	0.500	0.500	Best COA	1	Value
Effectiveness	0.300	0.300		1	Value
Logistics	0.150	0.150		1	Value
Utilize Surprise	0.050	0.050		1	Value
Force Protection	0.429	0.214	Continuity	2	Value
Attrition	0.429	0.214		2	Value
Enemy Reaction	0.143	0.071		2	Value
Flexibility	0.152	0.045	Effectiveness	2	Value
Superiority	0.303	0.091		2	Value
Damage	0.242	0.073		2	Value
Covering Tasks	0.273	0.082		2	Value
Integration	0.030	0.009		2	Value
Speed	0.125	0.019	Logistics	2	Measure
Support	0.625	0.094		2	Measure
Mobility	0.250	0.038		2	Measure
Weather	0.100	0.005	Utilize Surprise	2	Measure
Day/Night	0.600	0.030		2	Measure
Unpredictability	0.300	0.015		2	Measure
Shield for OCA	0.333	0.071	Force Protection	3	Measure
Active Air Defense	0.667	0.143		3	Value
Friendly Loss	1.000	0.214	Attrition	3	Measure
Enemy reaction to the COA	1.000	0.071	Enemy Reaction	3	Measure
Closeness	0.500	0.023	Flexibility	3	Measure
Assumptions	0.167	0.008		3	Measure
Utilize Multi Role	0.333	0.015		3	Measure
Aerospace Superiority	1.000	0.091	Superiority	3	Measure
First Priority Targets	0.700	0.051	Damage	3	Measure
Second Priority Targets	0.200	0.015		3	Measure
Third and the other Priority Targets	0.100	0.007		3	Measure
First Priority Tasks	0.700	0.057	Covering Tasks	3	Measure
Second Priority Tasks	0.200	0.016		3	Measure
Third and the other Priority Tasks	0.100	0.008		3	Measure
Additional Services	1.000	0.009	Integration	3	Measure
Point Defense	0.600	0.086	Active Air Defense	4	Measure
Area Defense	0.200	0.029		4	Measure
HVAA Protection	0.200	0.029		4	Measure

In Table 4, this shows the relative importance of each value compared to the lowest weight of weather.

Table 4 Global Value Measurement and Relative Value versus Weather

Name	Global Values	Relative Values
Friendly Loss	0.2143	42.86
Support	0.0938	18.75
Aerospace Superiority	0.0909	18.18
Point Defense	0.0857	17.14
Shield for OCA	0.0714	14.29
Enemy reaction to the COA	0.0714	14.29
First Priority Tasks	0.0573	11.45
First Priority Targets	0.0509	10.18
Mobility	0.0375	7.50
Day/Night	0.0300	6.00
Area Defense	0.0286	5.71
HVAA Protection	0.0286	5.71
Accessibility	0.0227	4.55
Speed	0.0188	3.75
Second Priority Tasks	0.0164	3.27
Utilize Multi Role	0.0152	3.03
Unpredictability	0.0150	3.00
Second Priority Targets	0.0145	2.91
Additional Services	0.0091	1.82
Third and the other Priority Tasks	0.0082	1.64
Assumptions	0.0076	1.52
Third and the other Priority Targets	0.0073	1.45
Weather	0.0050	1.00

IV. Application, Results, and Analysis

"A man who does not think and plan long ahead will find trouble right at his door." (Confucius)

It is better to generate scenario based alternatives for an operation planning. However, in this section 10 notional COAs have been produced without any scenario since general assessment measures were developed for this model. In addition, operation planning records and scenarios are confidential in every country. The 10 notional COAs are used to show how well the model works to rank the COAs. Then, the results are analyzed to understand the relationships between measurements, input, and the alternatives, output of the model.

4.1 Alternative Generation

Planners need to determine which alternatives or COAs should be considered in the model. There are some techniques use to generate alternatives. Howard recommends the strategy table as the most important idea in creating alternatives (Howard, Decision Analysis: Practice and Promise 1988). The purpose of constructing a strategy table is to identify strategies that will be covered during the generating of an alternative.

To construct a strategy table, each of the strategic decisions in the hierarchy is placed in the top cell of a separate column (Abbas and Howard 2011). After the strategy table is completed with potential alternatives for each decision, the next step is to make decisions on some strategies. Each strategy fits in different groupings from the potential alternatives for each strategy. For instance, Figure 17 shows an example of a strategy table with the four top tier objectives of our model. In general, users come up with hybrid

strategies that yield several good alternatives. For example, some alternatives may be generated from a hybrid strategy which includes a mix of the strategies in Figure 17; using the continuity strategy of combined force, effectiveness strategy of total force, and logistic considerations and utilizing the surprise strategies of partial force.

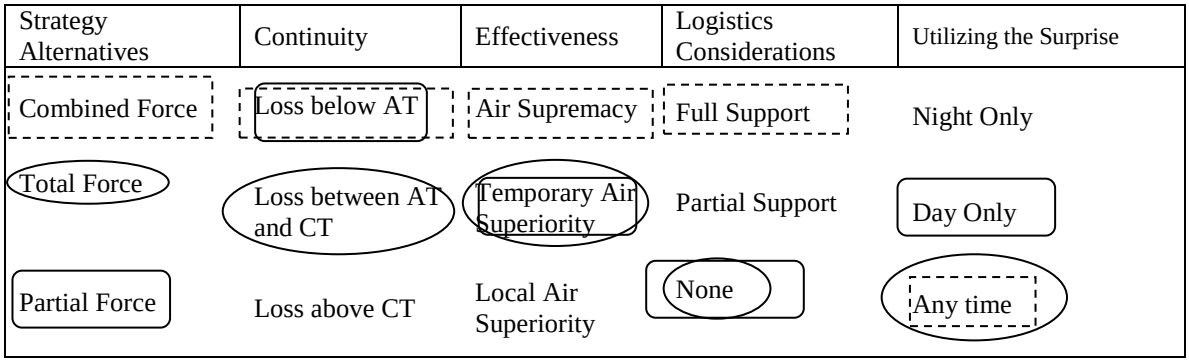

Figure 17 Example Strategy Table

In doing so, the values of generated alternatives, COAs, for each measurement are shown in Table 5.

Table 5 Alternative COAs

Alternative Name	COA1	COA2	COA3	COA4	COA5	COA6	COA7	COA8	COA9	COA10
Speed	44	144	134	158	81	129	92	47	62	120
Support	90	60	45	85	80	65	95	50	55	65
Mobility	Low Mobility	High Mobility	Low Mobility	High Mobility	Low Mobility	High Mobility	Moderate Mobility	Moderate Mobility	High Mobility	Low Mobility
Weather	AWX	AWX	non-AWX	CAVOK	AWX	CAVOK	non-AWX	AWX	non-AWX	AWX
Day/Night	SR+2 to SS-1	SS+3 to SR-1	SR-1 to SR+2	SS+3 to SR-1	SS+3 to SR-1	SR+2 to SS-1	SS+3 to SR-1	SR-1 to SR+2	SS-1 to SS+3	SS-1 to SS+3
Unpredictability	Low	Low	Low	Low	High	High	High	Low	Low	High
Shield for OCA	1.2	1.7	1.2	0.6	1.5	0.5	0.8	0.7	0.8	1.1
Friendly Loss	85	60	70	10	25	55	25	80	30	45
Enemy reaction	Doct.	Irration.	Doct.	Innov.	Surren.	Irration.	Doct.	Doct.	Doct.	Irration.
Closeness	38	15	55	32	15	23	10	52	38	63
Assumptions	2	3 and more	2	0	0	1	1	2	1	2
Utilize Multi Role	44	28	33	67	49	36	76	65	20	57
Aerospace Superiority	552	216	240	360	144	72	120	96	168	192
First Priority Targets	55	65	70	80	60	80	100	80	85	90
Second Priority Targets	35	50	60	40	20	100	35	65	70	45
Third and other Priority Targets	80	55	95	75	80	20	35	45	70	50
First Priority Tasks	95	65	75	80	95	90	65	75	85	60
Second Priority Tasks	35	85	90	40	80	90	35	35	50	40
Third and other Priority Tasks	20	95	30	60	25	40	50	95	25	30
Additional Services	Single	Single	All	Single	Plus One	All	Single	Plus One	Single	Single
Area Defense	45	90	85	55	60	65	75	70	85	50
Point Defense	100	50	40	80	45	35	65	80	70	85
HVAA Protection	70	45	100	90	85	55	50	90	55	60

4.2 Alternative Scoring and Ranking

Alternatives need to be scored in order to rank them in relation to weighted measurements since we have generated alternatives. Furthermore, all the parameters of Equation (15), which sums up the related scores of each weighted values and measurements, should be known to plug into before calculating overall values of each alternative to put them in order. Overall values don't represent the importance of the

alternatives so that they shouldn't be used to make a comparison. It is a value that is used to rank the alternatives. On the other hand, the overall value may give a sense of how far the alternative is away from a perfect one.

The data of the 10 alternatives and the results for best COA were fed into the value model to produce overall scores for each COA. Using Hierarchy Builder it scored each of the COAs and consolidated it by branch in Figure 18. Although it doesn't have every highest branch value except in continuity, COA5 has the overall highest value given the input measures.

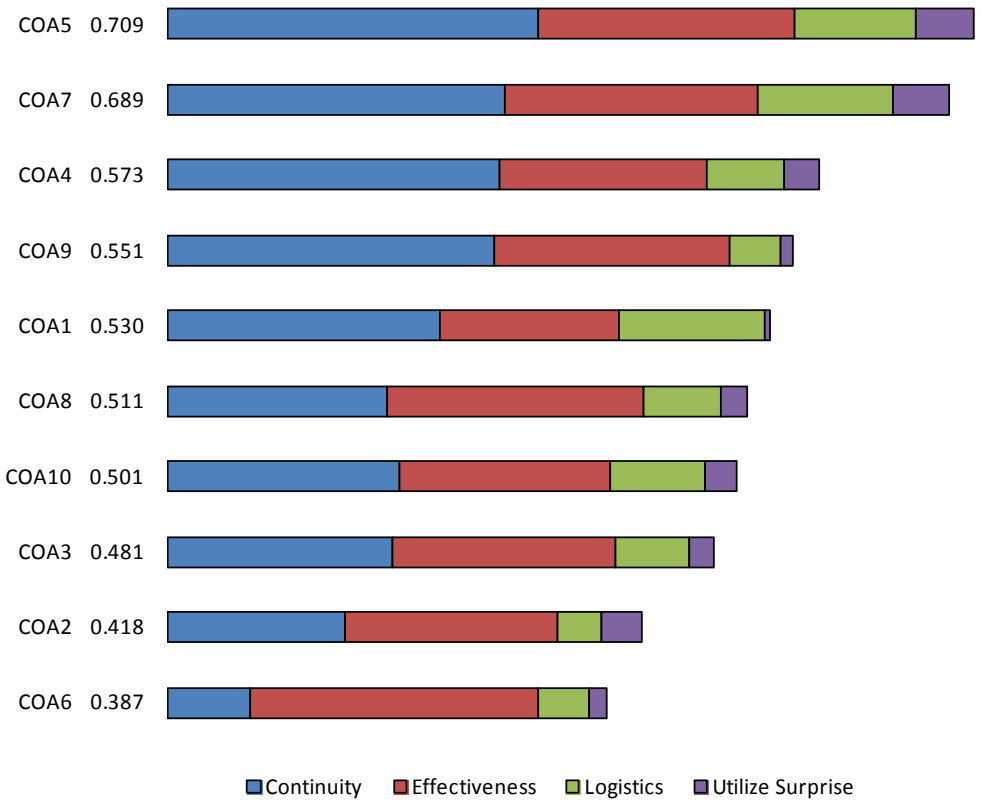

Figure 18 Overall Scores for Each COA by Branch

The scores where each COA's value is broken down by the 23 evaluation measures are shown in Figure 19. Analyzing the figure, the relative comparison of measurements can be understood by the size of same colored bars pertaining to a corresponding COA. The white part of every measurements the value gap for the related attribute. The most prominent measurement which has the highest weight is friendly loss. This implies that during generating COA planners should consider not only to eliminate the enemy but also to protect their force for the further phases of the operation.

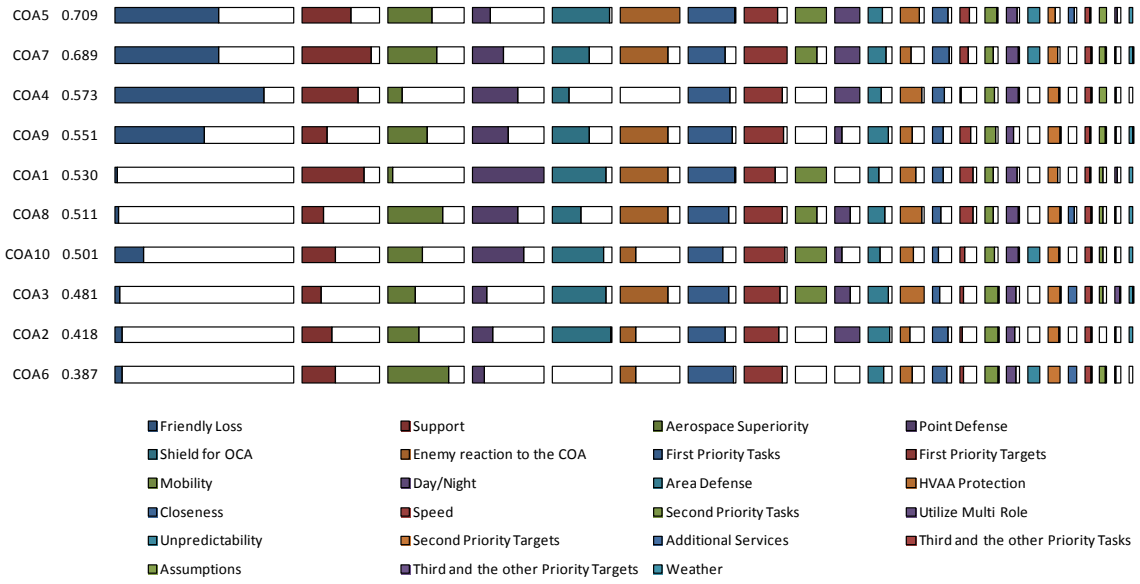

Figure 19 Scores for Each COA Broken Down by Measure

As seen in Table 4, it can be noted that the six most important measurements will account for close to 62% of the overall value model. These top six measurements are Friendly Loss, Logistic Support, Aerospace Superiority, Point Defense, Shield for OCA, and Enemy reaction to the COA. The stoplight chart which shows gaps and color graph red, orange, yellow, green based on quartiles for these top measures are exposed in

Figure 20. This chart gives a hint that the major part for a better score comes from continuity objectives. Moreover, effectiveness and logistics objectives chase it respectively. On the other hand, the gaps in each measure demonstrate the lost opportunity for improvement of corresponding measure of alternatives.

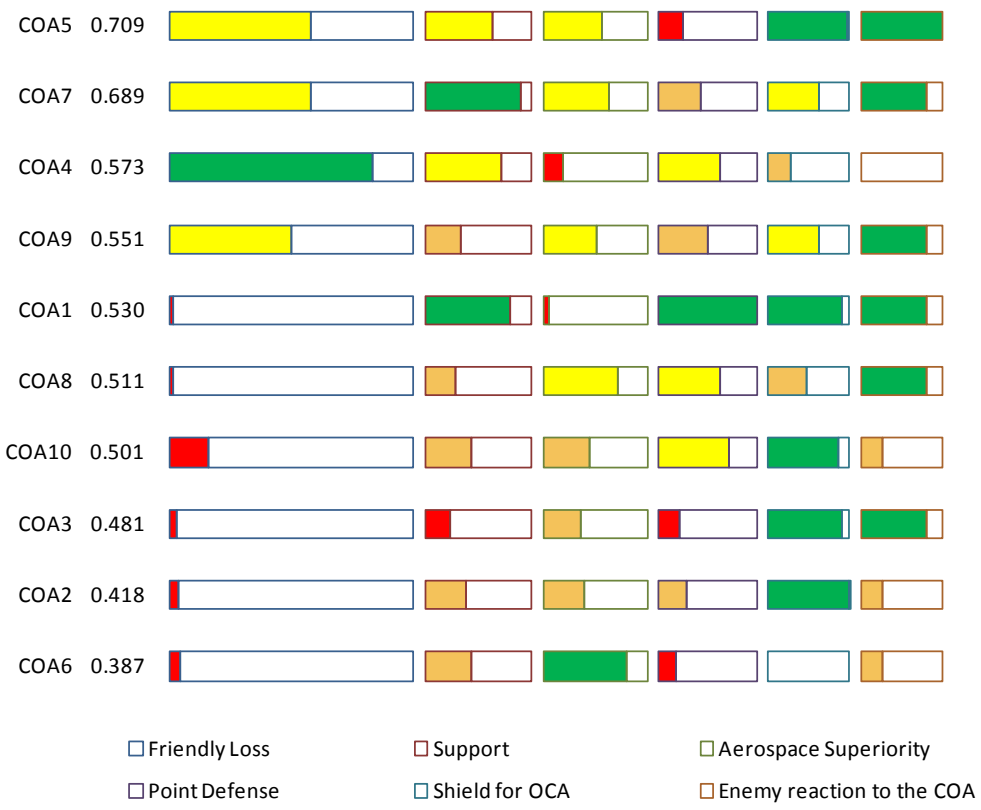

Figure 20 Scores for Each COA Broken Down by Top 6 Measure

The contributions of continuity objective scores germane to COAs including quartile lines within each bar are shown in Figure 21. It can be observed that some COAs have good force protection score like COA1 even though they have very low attrition scores. The underlying reason is that COA1 expects the longest time to reach required

aerospace superiority, 552 hours. Thus, the high expectation for friendly loss is normal with a long-run operation.

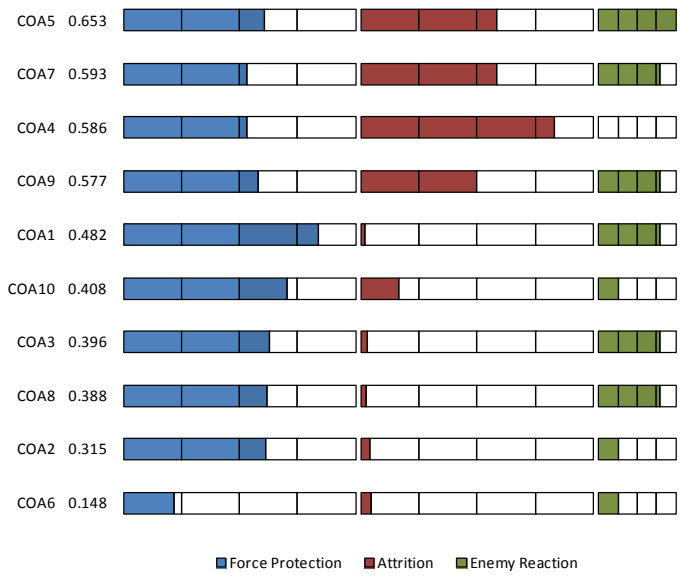

Figure 21 Scores for Each COA Broken Down by Continuity Objective

As seen in Figure 22, COA6 has the highest score in effectiveness objectives. It is noticeable that top three COA have high integration score. This can accurately be interpreted as integration increases the effectiveness of the plan.

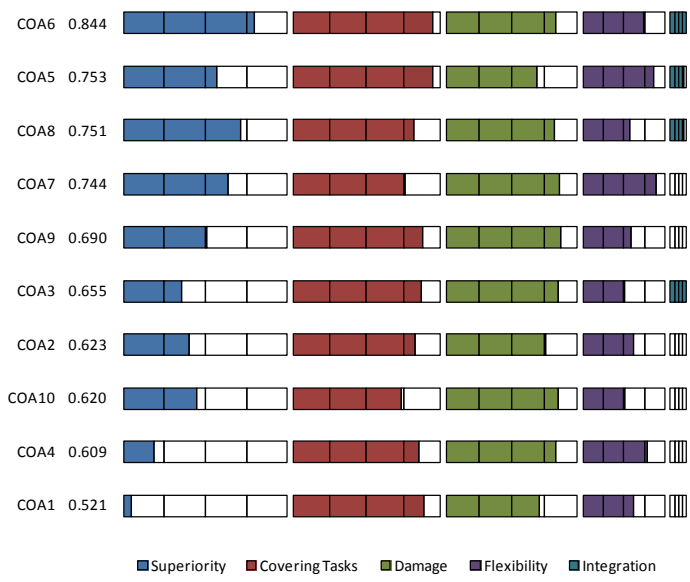

Figure 22 Scores for Each COA Broken Down by Effectiveness Objective

Although, COA1 is in the fifth order overall, exposed in Figure 18, it has the highest Logistics score as shown in Figure 23. Finally, Figure 24 shows the scores of utilized surprise objective.

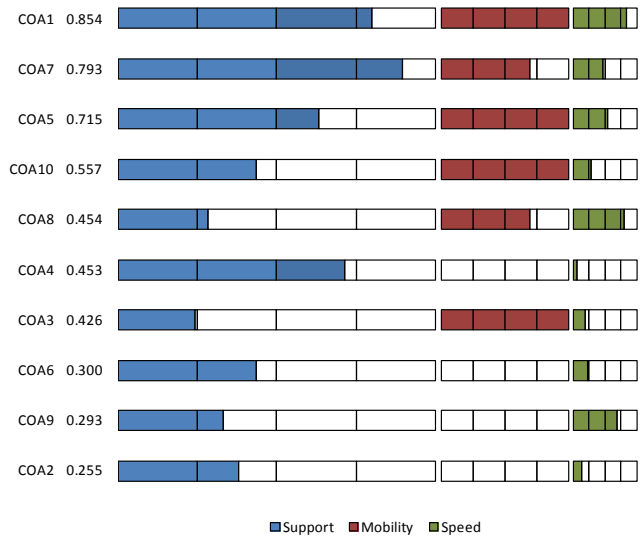

Figure 23 Scores for Each COA Broken Down by Logistics Objective

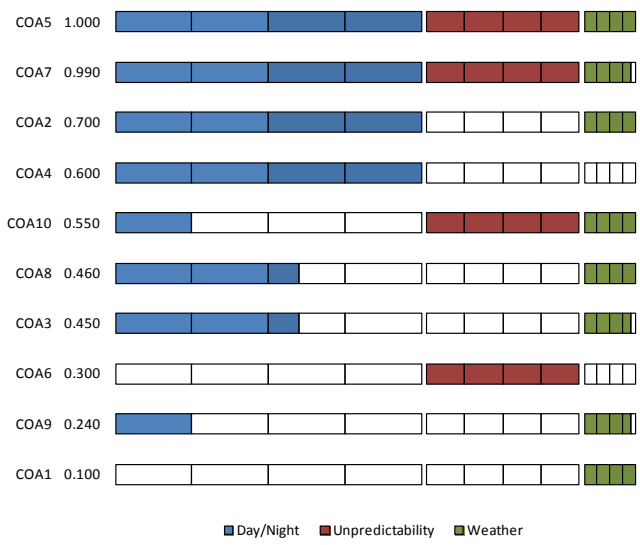

Figure 24 Scores for Each COA Broken Down by Surprise Objective

4.3 Sensitivity Analysis

Once the VFT Model with weights and alternatives has been constructed, it can be used to perform a sensitivity analysis to find out the impact on the ranking of alternatives of changes in various model parameters (Kirkwood 1997). To do a sensitivity analysis, one of attributes is selected and its global weight is manipulated to provide helpful insight to the decision-maker. As the weights for the selected attribute varies, the weights of the rest is changed by Equation (16) (Kirkwood 1997).

$$w_i = (1 - w_s)\left(\frac{w_i^0}{\sum_{i=1}^{m} w_i^0}\right) \tag{16}$$

w_i: all changing weights in sensitivity analysis

w_s: the weight under consideration

w_i^0: all changing weights' original values in the first model

m: the number of dependent weights

Hierarchy Builder displays the sensitivity analysis with a corresponding graph. The horizontal black line represents the current weight of the selected attribute. The other colored lines exemplify the image of score related to alternatives. The points which colored lines cross the black line indicate the particular ranking of COA. In addition, the slope of the line has a meaning. A flat line means the related COA is not sensitive to the selected weight change which is good; in contrast, slopped line illustrates the dependency of COA to it.

The SME group prefers to give the highest weight to the continuity objective, 0.5. Figure 25 illustrates how the change in the weight of continuity may alter the rank of COA. The current best COA, COA5, can only be defeated if DM changes his preference for the continuity with a weight less than around 0.23. Hence, COA1 is the best alternative when the weight of continuity is between 0 and 0.23. Besides, COA4 and COA9 are not sensitive to continuity. They keep their scores whereas the rest lose points which can be understood with the slope of the lines in the graph.

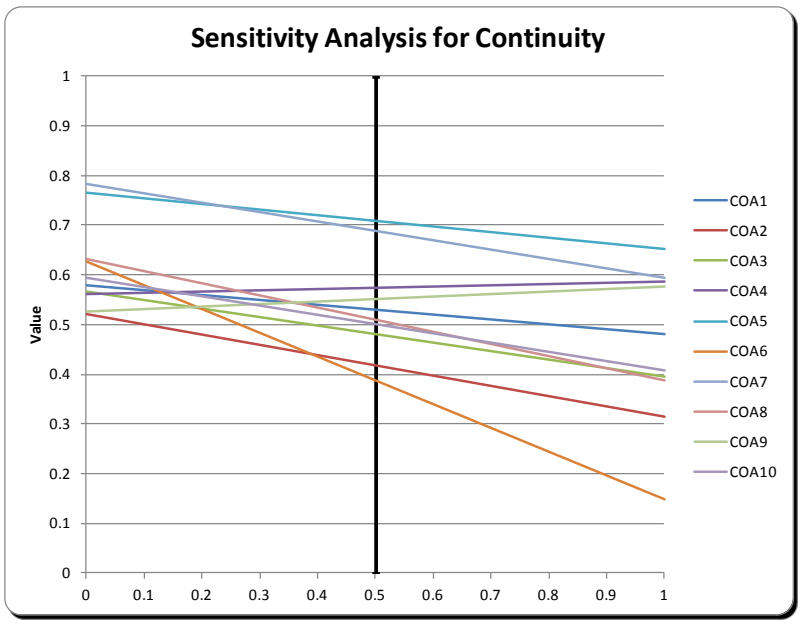

Figure 25 Sensitivity Analysis for Continuity Objective

COA5 has the best score with effectiveness weight between 0 and around 0.8. COA6 will be the best alternative when DM prefer to weight effectiveness objective more than 0.8. On the other hand, COA6 is the most sensitive to effectiveness.

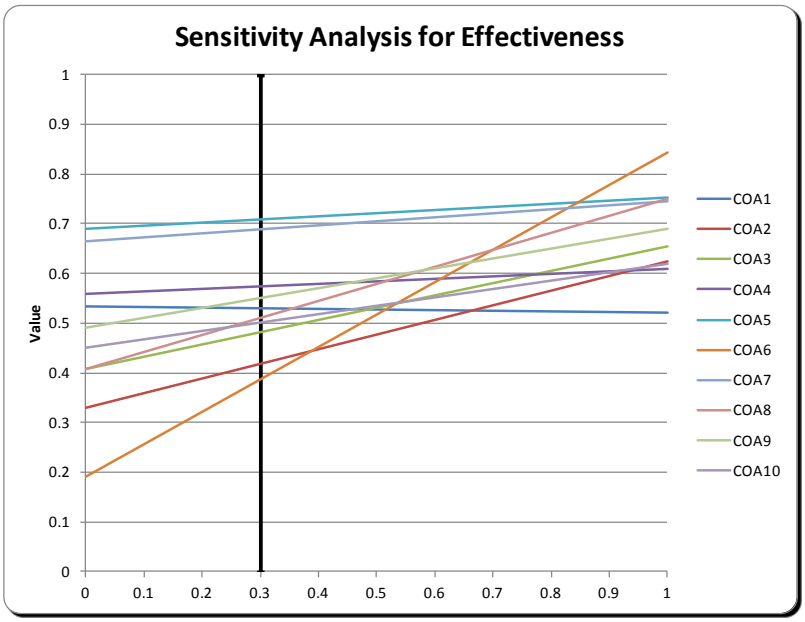

Figure 26 Sensitivity Analysis for Effectiveness Objective

Logistics can affect the alternative ranking in three break points as seen in Figure 27. COA5 keeps the lead under 0.3 where COA7 takes the lead. If the DM decides to quantify the importance of the logistics objective more than 0.75, COA1 will be the best choice.

The flatness of the COA5's line directly shows us that it doesn't depend on Logistics which is a desirable situation for OPLAN. However, this is not true for COA1 and COA7 due to their angle of lines.

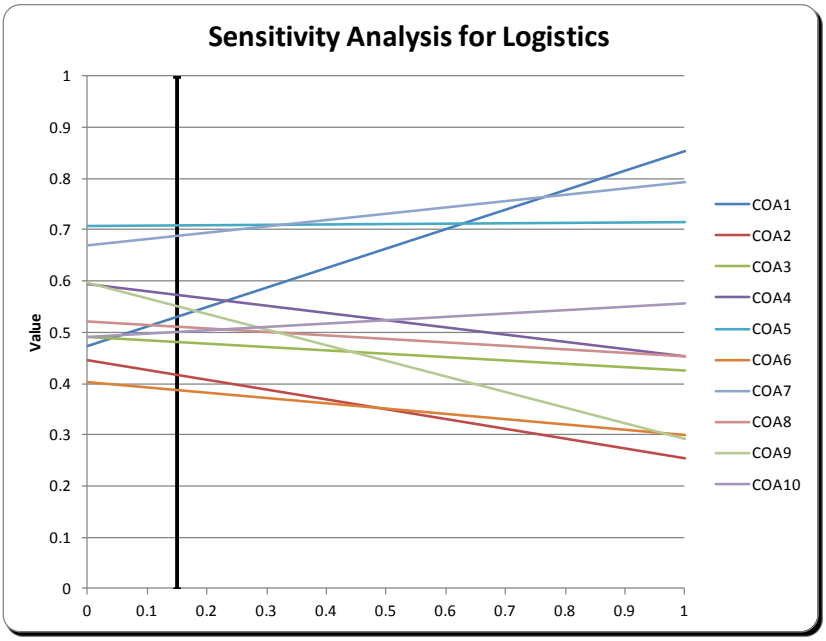

Figure 27 Sensitivity Analysis for Logistics Objective

In this model, there exists some attributes that don't change the ranking of best COA like utilize surprise objective as shown in Figure 28. Although COA5 has the

highest score regardless of utilize surprise objective weight manipulations, COA7 keeps following in pursuit of COA5.

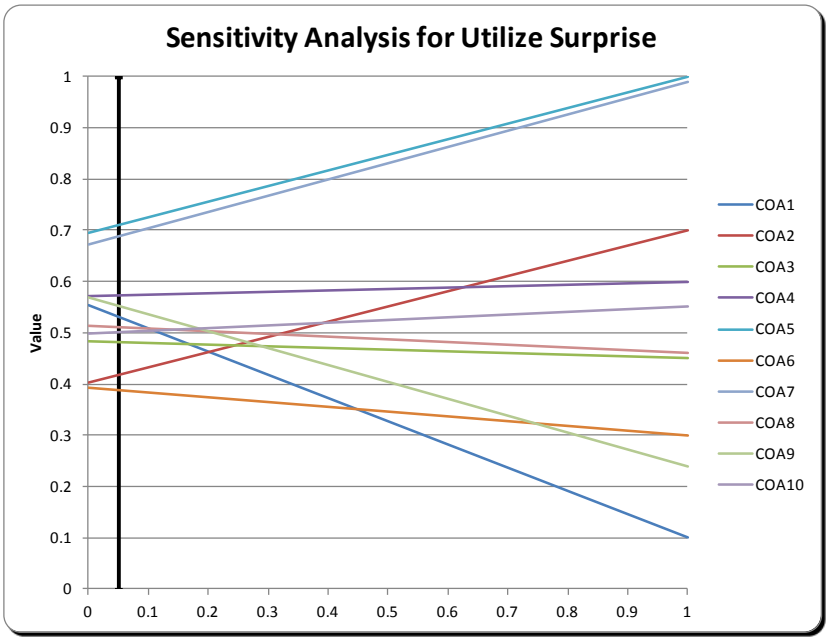

Figure 28 Sensitivity Analysis for Utilize Surprise Objective

Consequently, COA1 and COA5 are the best alternatives as a result of the sensitivity analysis over continuity objective. COA5 and COA6 are the best alternatives caused by the sensitivity analysis over effectiveness objective. COA5, COA7 and COA1 are the best alternatives on account of the sensitivity analysis over logistics objective. Finally, COA5 is dominant due to the sensitivity analysis over utilize surprise objective. Therefore, all the other alternatives are always dominated with these alternatives. Thus, sensitivity analyses validate the scoring and the ranking of the alternatives with the given preferences.

V. Summary, Conclusions and Future Work

"When you're dying of thirst it's too late to think about digging a well."
(Japanese Proverb)

In this chapter, Section 5.1 presents the summary of this research briefly, Section 5.2 summarizes the conclusions of this research and Section 5.3 offers recommendations for future work.

5.1 Summary of the Research

The purpose of this research is to develop a process which allows the DMs to asses COAs and help the planners to develop good alternatives. In order to meet the goal of this thesis, problem and the scope of the research are defined in Chapter 1, as well as research questions and assumptions are stated.

In Chapter 2, the three main topics of the thesis are explained. First, Strategic Planning is described in key effects and steps with an example from the business sector. Second, decision analysis is briefly clarified, and afterwards the steps of value-focus thinking that are used in this paper are demonstrated. Third, the operation planning process is selected in lieu of a case study for strategic planning so that model can be built. Because of that reason, operation planning and its procedures for developing COAs are elucidated. Finally, the contribution of this research is summarized at the end of the chapter.

In Chapter 3, the systematic methodology for any kind of strategic planning is primarily explained with the formulation of the model which is made by the help of implementing the VFT approach to select the best COA. The value hierarchy that is

created with SME group is explained. The evaluation measures developed for the model are all defined in detail. Examples of the single dimension value functions are illustrated before the weighting of the hierarchy is discussed.

In Chapter 4, notional alternative generation is used instead of scenario based alternatives for an operation planning due to confidentiality. Then, these 10 theoretical COAs are scored and ranked to show how well the model functions to order the options. Subsequently, sensitivity analyses are made with the main tier objectives to give the user an idea about the relationships between measurements (input) and the alternatives (output) of the model.

5.2 Conclusions

Decision making with multiple objectives is not an easy problem to solve or explain. The main purpose of these problems is to find out the best solution; in other words, the best decision. Although the greatest way to generate and analyze alternatives for the best solution is to work as a group, framing multi-objective decision problems need more than human effort. Therefore, computer based models are helpful to structure and solve the problem.

COA selection is an excellent example for multi-objective decision problems. As described in Chapter 2, it is an essential step for any kind of strategic planning. Very basically, strategic planning spots what the organization wants to do and how it is going to be done. This planning process is a recurrent consideration to reach the goals of the organization, and how this affects the outcome of the organization.

The goals stated within any kind of strategic plan compel the planners to find a best course of action for the organization to follow in order to achieve them. This implies the main question of this thesis which is declared in the first chapter; *"Which courses of action (COA) is the best of the given scenario for strategic planning in order to achieve the objectives?"*

Value-focused thinking modeling which can easily be applied to computer is a perfect fit to answer the main question. This research tries to show that with a case study - air force operation planning. The model is built to facilitate the crucial step of this process. Developing course of actions for a given operation planning connects mission analysis to publishing the order.

Planners should understand and comprehended the given directives and Commander's intent before developing COAs. The generated COAs are supposed to be briefed to get an approval. Therefore, COAs need to be well developed. The model offered in this thesis will help the planners not only asses and generate COAs but also to present them to DM since it is totally based on the weights of SME group on behalf of DM.

This model is improved in seeking the answers of the sub level questions. There are four sub-objectives next to the fundamental objective. The model is looking for maximizing these four sub-objectives. In doing so, it uses 9 values and 23 measurements. All of these are briefly shown in Table 2 with their upper and lower bounds. Although this model can assess any type of COA due to its common measures, evaluation measurements are subject to change with the user.

VFT models are not just for ranking the alternatives. However, they show the DM the big picture which can be inferred from either the sensitivity analysis or ranking scores with the help of some graphs like the stoplight chart. When we have combine Figure 26 and Figure 29 together, the cons and pros of any COA will be shown and understood by every stakeholder. In addition, this analysis gives an idea to the decision-maker about how far is the best alternatives from the ideal point. For example the white parts in every bar represent the potential improvement of corresponding objectives per alternatives.

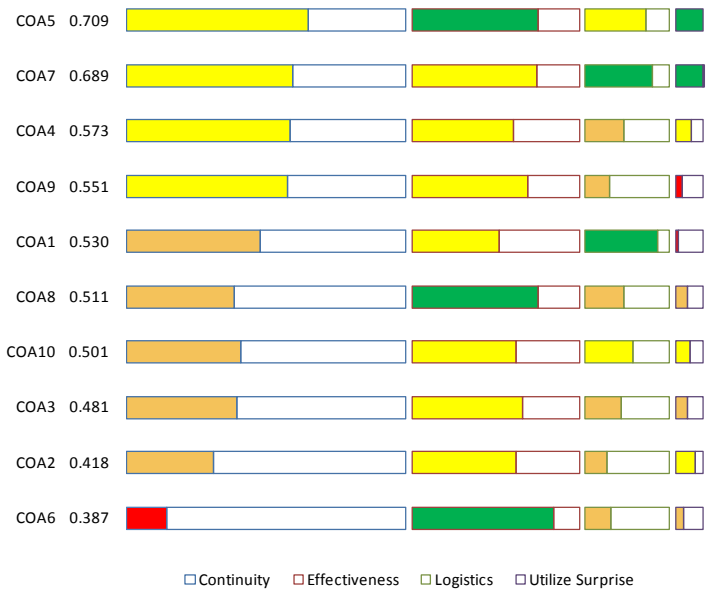

Figure 29 Stoplight Chart of Sub-objectives

Consequently, VFT models promote the flexibility of analyzing the decision; therefore, it eases well being of the communication between the planners and the decision-maker. Briefly, the major benefits of VFT for selecting the best COA for strategic planning are engaging the planners to capture the objectives, evaluating alternatives, creating alternatives, and improving communication.

5.3 Future Work

The model in this research doesn't include the risk and the cost associated with COAs. In addition, the target priorities for the damage measure and air defense analyses are assumed to exist. Therefore, it will be better to improve the model with future works. First, although it may be sometimes thought as unreasonable in most of the military condition, a cost analysis can be made for each COA with regard to VFT model but not in it. Second, risk analysis parallel to the VFT model will increase the precision of selecting best COA. Finally, an optimization analysis for target priority can be made to measure the damage ability of linked COA.

Appendix A. VFT Hierarchy and SDVFs

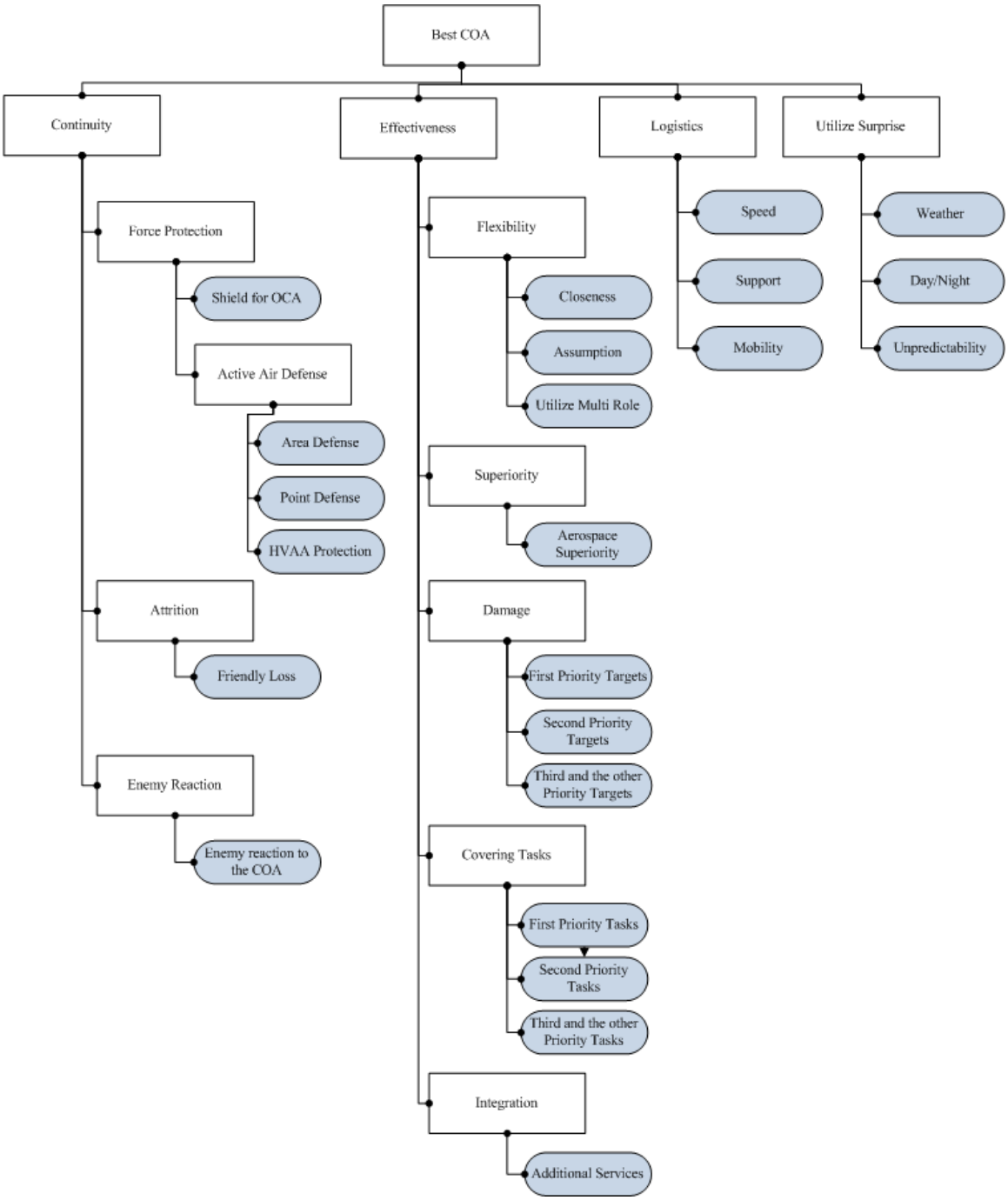

Figure 30 Value Hierarchy

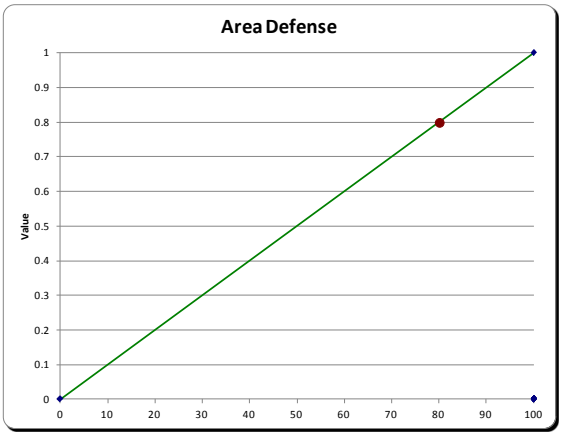

Figure 31 Area Defense SDVF

xH: 100, xL: 0, ρ: 15,000

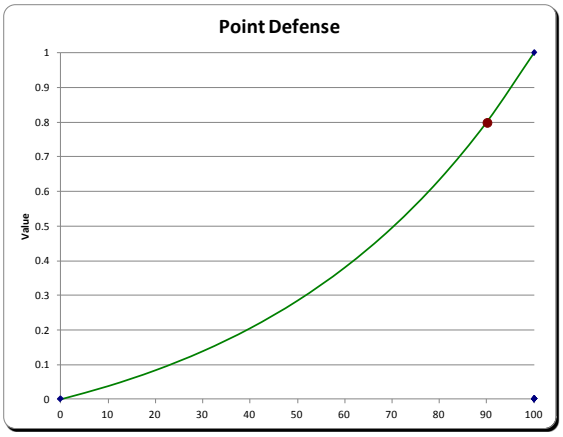

Figure 32 Point Defense SDVF

x^H: 100, x^L: 0, ρ: -54.27

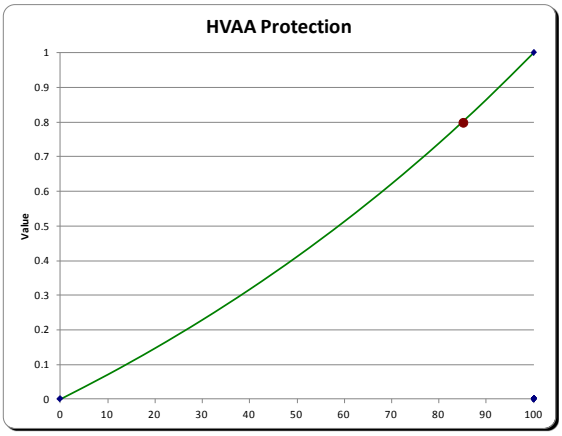

Figure 33 HVAA Protection SDVF

x^H: 100, x^L: 0, ρ: -140.053

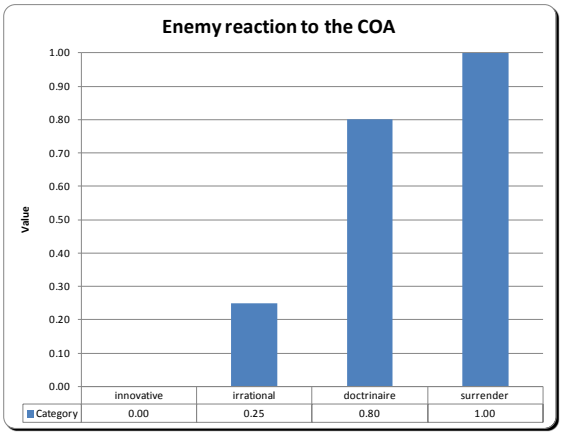

Figure 34 Enemy Reaction to the COA SDVF

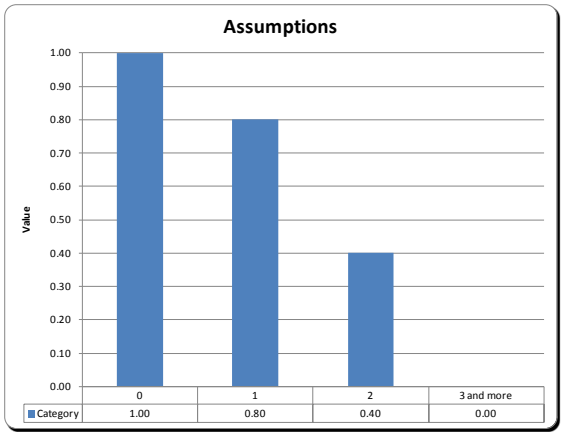

Figure 35 Assumptions SDVF

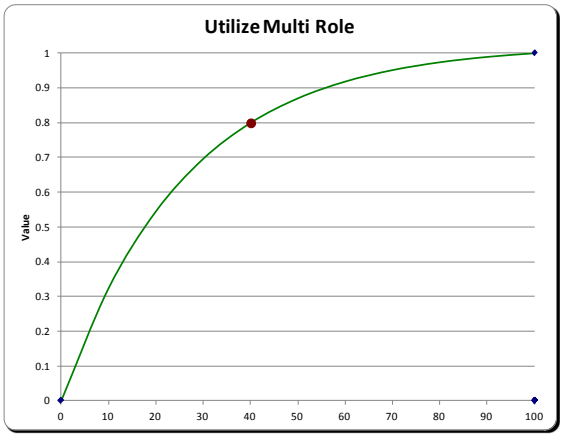

Figure 36 Utilize Multi Role SDVF

x^H: 100, x^L: 0, ρ: 26.287

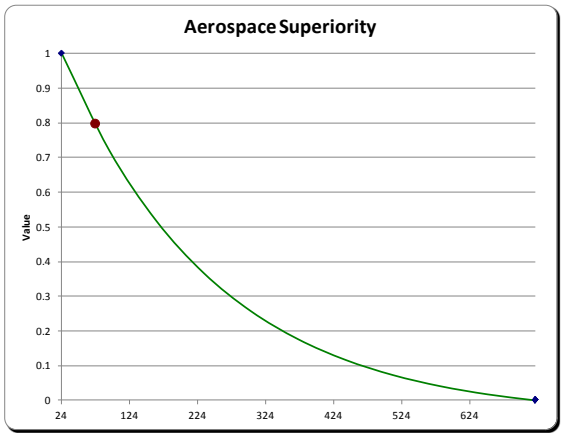

Figure 37 Aerospace Superiority SDVF

x^H: 24, x^L: 720, ρ: -225.401

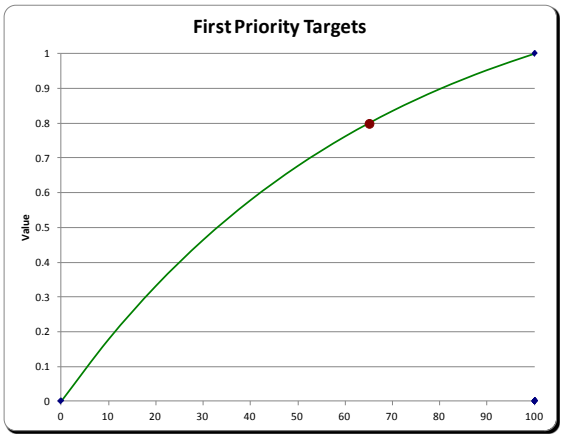

Figure 38 1st Priority Target SDVF

x^H: 100, x^L: 0, ρ: 67.4568

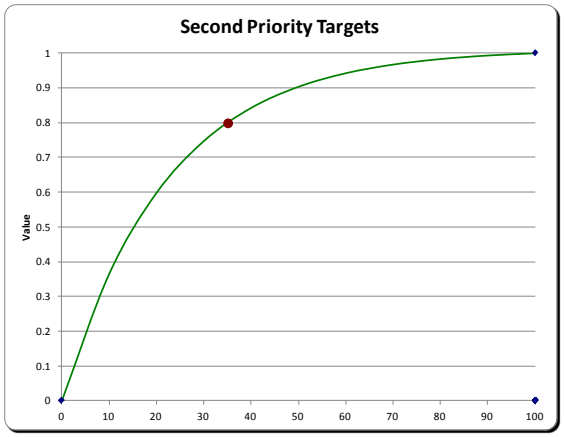

Figure 39 2nd Priority Targets SDVF

x^H: 100, x^L: 0, ρ: 22.3564

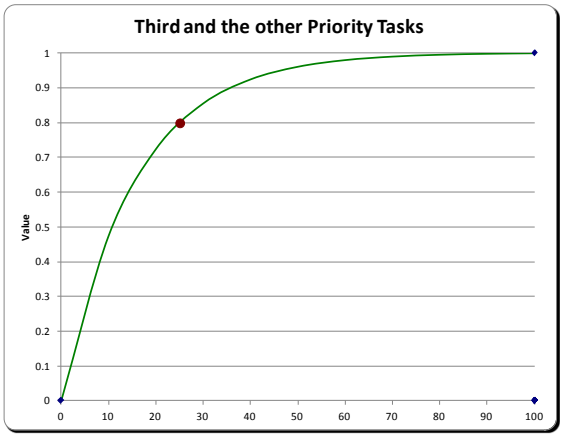

Figure 40 3rd and the other Priority Targets SDVF x^H: 100, x^L: 0, ρ: -22.7278

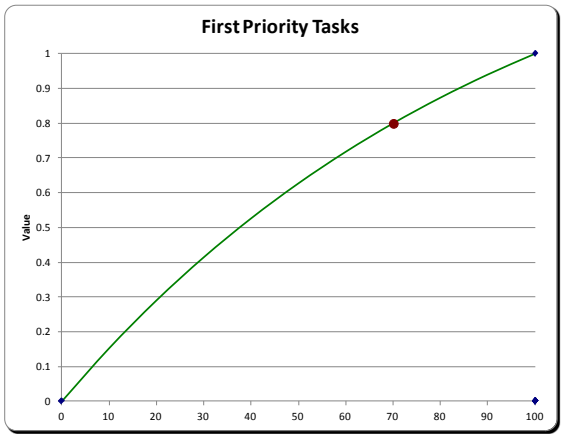

Figure 41 1st Priority Tasks SDVF

x^H: 100, x^L: 0, ρ: 96.1627

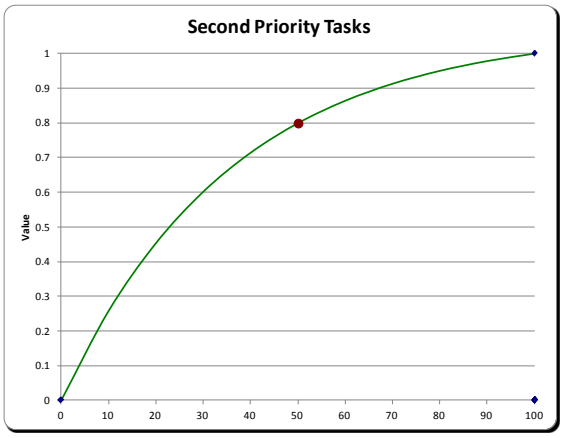

Figure 42 2nd Priority Tasks SDVF

x^H: 100, x^L: 0, ρ: 36.1881

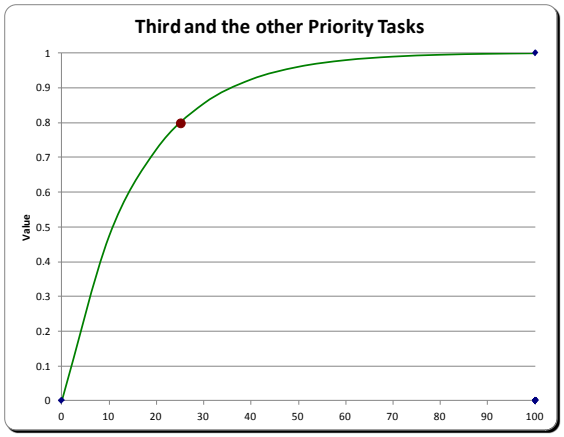

Figure 43 3rd and the other Priority Tasks

SDVF x^H: 100, x^L: 0, ρ: 15.5877

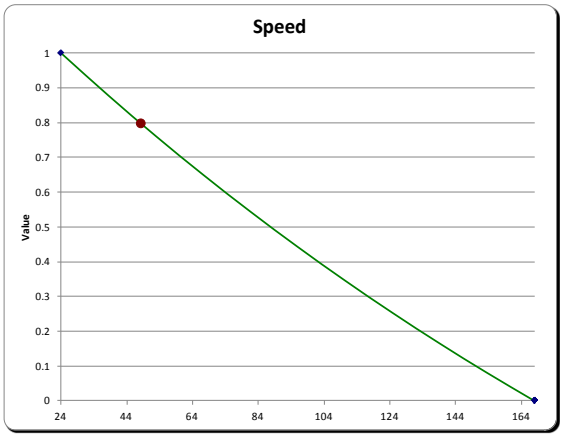

Figure 44 Logistics Speed SDVF

x^H: 24, x^L: 164, ρ: -312.979

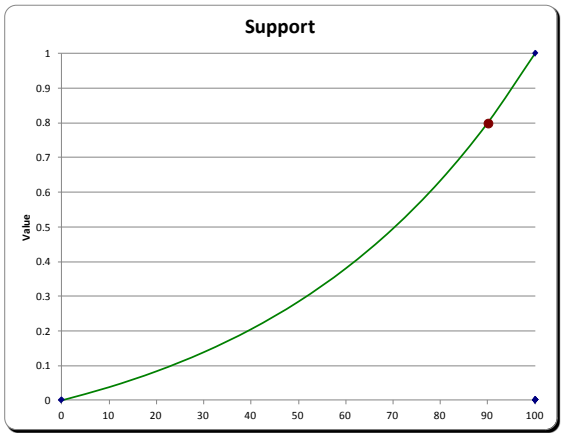

Figure 45 Logistics Support SDVF

x^H: 100, x^L: 0, ρ: -54.2706

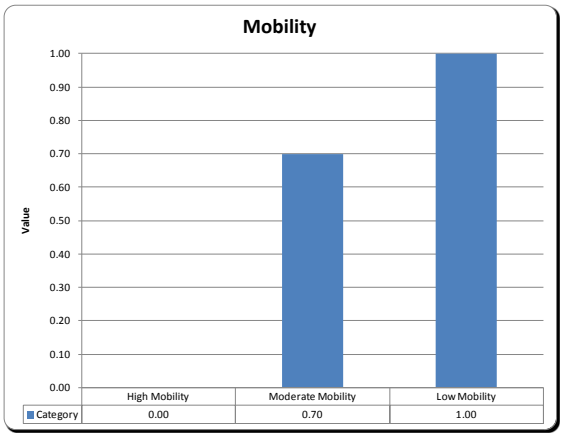

Figure 46 Logistics Mobility SDVF

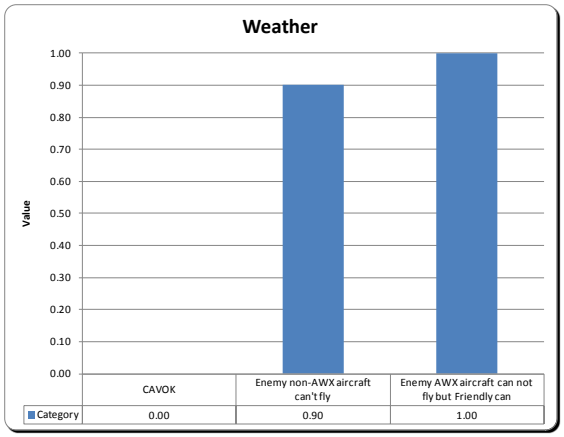

Figure 47 Weather SDVF

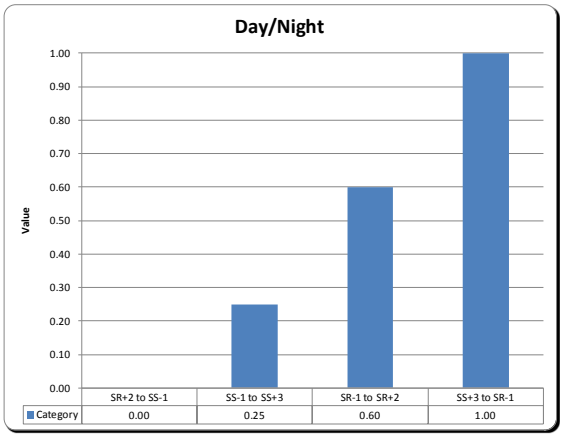

Figure 48 Day/Night SDVF

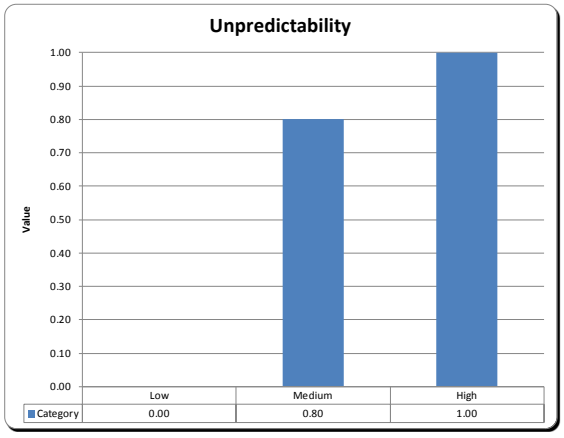

Figure 49 Unpredictability SDVF

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Vita

Major Ahmet Ozdemir graduated from Maltepe Military High School in Izmir, Turkey. He entered undergraduate studies at the Turkish Air Force Academy, Istanbul where he graduated with a Bachelor of Science degree in Industrial Engineering in 1999. His first assignment was at Cigli AFB, Izmir as a student in Pilot Training. He was assigned to the 143rd F-16 Fighter training squadron, Ankara in 2001. He was assigned to 161st Squadron, Bandirma AFB in 2002 and flew there for five years as a fighter pilot. In 2007, he entered Turkish Air Force Collage, Istanbul. After graduation in 2009 he was assigned to the Department of Operation, Air Force HQ Ankara and served there for two years. He entered the Graduate School of Engineering and Management, Air Force Institute of Technology in 2011. He has more than 1000 hours in the F-16. Ahead of graduation, he will be assigned back to Air Force HQ, Ankara.

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Air Force Institute of Technology
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14. ABSTRACT

Like almost all real life problems, Strategic planning is a good example of a problem with more than one objective. One of the most important steps of strategic planning is to generate and evaluate the courses of actions (COA) which can fulfill the mission and vision of the organization. This is a critical process since it is impractical to start the executed COA over.

In this research, value-focused thinking (VFT) is used as a decision analysis tool to assess COAs. A general model is created to select the best COA for strategic planning such as air force operation planning. To validate the model, notional courses of actions are developed, ranked, and evaluated to include using sensitivity analysis.

15. SUBJECT TERMS

Strategic Planning, Operation Planning, Course of Actions (COA), Multi Objective Decision Analysis, Value Focused Thinking, Value Hierarchy, Sensitivity Analysis

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U	U	U	UU	91	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636, ext 4523; e-mail: Jeffery. Weir@afit.edu

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